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THE

# AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

## ART. I.—*On the Energy of the Cathode Rays;* by W. G. CADY.

[An investigation carried out at the Physical Institute of the University at Berlin.]

IT has long been known that the cathode rays possess a considerable amount of energy; yet the relation between this and the other discharge phenomena has hitherto received but little attention. Ebert and Wiedemann,* E. Wiedemann,† and Ewers‡ measured the energy of cathode rays by means of calorimeters. For exact work, however, the thermo-element is to be greatly preferred. Among the recent investigations based upon the emission hypothesis, this method has been employed by J. J. Thomson §; O. Berg has also used a thermo-element in his work with the cathode rays.‖

According to the emission hypothesis there exists the following relation between the energy of the cathode rays, potential of discharge, and amount of electricity transported by the rays. Suppose that we have a bundle of rays given off from a cathode of potential $V$, and striking a metallic conductor which is led to earth through a galvanometer; let the conductor be struck by $N$ particles per second. We will at first assume that the entire charge of the particles, as well as all their energy in the form of heat, is given up to the conductor. Then if $v$ [cm. sec$^{-1}$] be the velocity of the particles, and $m$

* H. Ebert and E. Wiedemann, Sitzungsb. der phys. med. Soc. zu Erlangen, Dec. 14, 1891.

† E. Wiedemann, Wied. Ann., lxvi, p. 61, 1898.

‡ P. Ewers, Wied. Ann., lxix, p. 167, 1899.

§ J. J. Thomson, Phil. Mag., xliv, p. 293, 1897.

‖ O. Berg. Ber. d. naturforsch. Gesellsch, zu Freiburg i. Br. XI, vol. ii, p. 73, July, 1899.

[gr.] their mass, we have for the amount of heat given up to the conductor

$$Q = N \cdot \tfrac{1}{2} m v^2 \qquad (1)$$

(ergs per second).

If the charge on each particle be $\varepsilon$, we shall have flowing to earth through the galvanometer a "cathode-current" of intensity

$$i = N \cdot \varepsilon \qquad (2)$$

Now the kinetic energy of each particle is

$$V \cdot \varepsilon = \tfrac{1}{2} m v^2. \qquad (3)$$

Hence

$$Q = N \cdot V \cdot \varepsilon = i \cdot V,$$

or

$$\frac{i V}{Q} = 1. \qquad (4)$$

According to Starke's investigations,* a part of the cathode rays are reflected. This can have no effect upon the above, provided that after reflection the velocity of the rays remains unchanged; and indeed the measurements made by Merritt† upon the deflection of reflected cathode rays seem to show this to be the case. We will, however, assume for the present that upon reflection the energy of each particle is diminished in the ratio $r' : 1$, while the charge remains unchanged. Then if the fraction $r$ of the rays be reflected, we have

$$Q = N(1-r) \cdot \tfrac{1}{2} m v^2 + N r (1-r') \cdot \tfrac{1}{2} m v^2 = \tfrac{1}{2} N m v^2 (1 - r r') \qquad (1a)$$

$$i = N \varepsilon (1-r) \qquad (2a)$$

$$V \varepsilon = \tfrac{1}{2} m v^2 \qquad (3a)$$

$$\frac{i V}{Q} = \frac{1-r}{1-rr'}. \qquad (4a)$$

If $r' = 1$ (Merritt), we have still $i V/Q = 1$. If in the limiting case $r' = 0$, then $i V/Q = 1 - r$.

These relations were investigated experimentally as described in the following paragraphs.

### *Apparatus.*

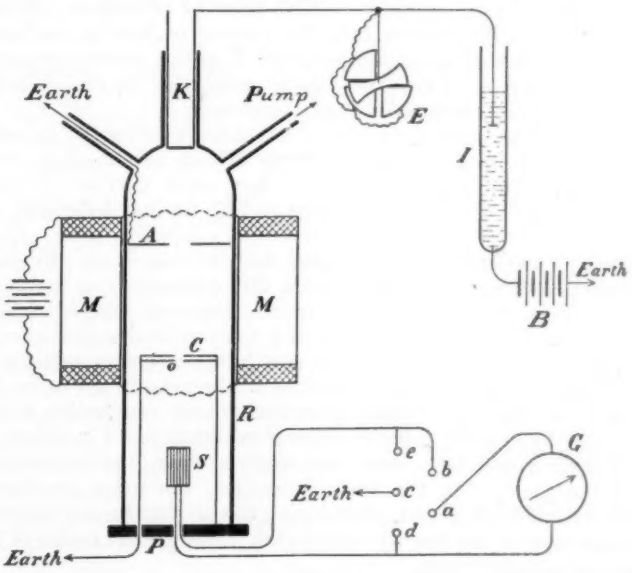
Fig. 1 shows the arrangement of apparatus at first used. For measuring the energy $Q$ a thermo-element was here employed; it was later displaced by a bolometer (see below.) The thermo-element, $S$, was of the Melloni type, consisting of 49 bismuth-antimony couples each $25^{mm}$ long; the exposed surface of the junctions was $196^{mm^2}$. It was placed inside the

* H. Starke, Wied. Ann., lxvi, p. 49, 1899.
† E. Merritt, Phys. Rev., vii, p. 217, 1898.

Faraday cylinder $C$, which was connected to earth. The rays entered through the hole $o$, $6^{mm}$ in diameter. $R$ is the glass discharge-tube, $25^{cm}$ long, cemented to the glass plate $P$.

The copper bottom of the brass tube $K$ served as cathode; in order to reduce the heating as far as possible, a stream of water was kept constantly flowing through the tube. The anode $A$ was a zinc diaphragm.

1




The discharge current was furnished by a secondary battery $B$ of 2288 cells, supplemented at times by a rotary transformer, so that a maximum E. M. F. of 5400 volts could be reached. The current was regulated by the Hittorf cadmium-iodide resistance $I$, and the potential of the cathode measured by means of the quadrant-electrometer $E$. $G$ is a Thomson galvanometer used in measuring the thermal and cathode-currents.

A serious source of error in observations lay in the evolution of gas from the cathode and other parts of the apparatus during discharge. This difficulty, so common in all gas-discharge work, was nearly always present, even after the apparatus had been in use for many hours. A partial remedy was found in running the air-pump slowly during observations, but even then the potential usually changed somewhat during the

minute or so necessary to take a set of readings. This is the chief cause of the irregularities in the numerical values given below.

Before the apparatus was put together, the thermo-element was calibrated as follows. The radiation from the blackened surface of a Leslie cube, filled with boiling water, passed through a series of diaphragms and fell upon the thermo-element. The constant of radiation for lampblack at 100° was taken according to Kurlbaum* as 0·0176 gr.-cal/sec. From the dimensions of the diaphragms could then be calculated, by use of the Stefan-Boltzmann law, the amount of heat $Q_0$ radiated from the hot surface at temperature $T$ to the thermo-element at temperature $t$. Like the Leslie cube, the thermo-element was also covered with a layer of lampblack.

The galvanometer deflection $s_0$ was observed after the thermo-element had been exposed for one minute to radiation from the cube. The amount of heat per scale division is then $e = Q_0/s_0$, and the amount corresponding to the deflection $s$ is $Q = s.e.$

During calibration the thermo-element was in air at atmospheric pressure; when in use with the cathode rays, it was in a partial vacuum, and moreover the layer of lampblack had then been removed. This would tend to make the rise in temperature of the junctions in the latter case greater than in the former, assuming the quantity of heat supplied to be the same: for the loss of heat by radiation and conduction to the air must have been greater during calibration. The effect of this error would be to make the observed energy of the cathode rays too great; but the error is smaller, the more the loss of heat by conduction and radiation to the air can be neglected in comparison to the loss by conduction through the metal of the thermo-element itself.

In measuring the cathode-current, the contact *ac* (fig. 1) was closed, thereby connecting the thermo-element to earth through the galvanometer. For the thermal circuit, *ab* was closed, and at the same time either *ce* or *cd*, since it was necessary to connect some point to earth. But when for example *cd* was closed, it was found that a small fraction of the cathode-current also flowed to earth through the galvanometer, along the path *SbaGdc*. Closing *ce* caused approximately the same deflection in the opposite direction. Hence the mean of the two readings could be taken as the deflection for the thermal current alone.

In order to eliminate the effect of heat radiated from the cathode, the rays were deflected before each observation by

* F. Kurlbaum, Wied. Ann., lxv, p. 759, 1898.

means of the coils MM (fig. 1); the small remaining galvanometer deflection was then subtracted from the total deflection with rays falling.

*Observations with Thermo-element.*

The value $i.V$ (eq. 4) in gram-calories is cathode-current in amperes $\times$ difference of potential in volts $\times$ 0·24. Pressures are always given in mm. of mercury.

The first measurements yielded values of $iV/Q$ much greater than 1, as shown in the following table:

TABLE I.

| Pressure. | $i \cdot 10^7$ Amp. | $V$ | $Q \cdot 10^5$ gr.-cal. | $iV/Q$. |
|---|---|---|---|---|
| 0·067 | 152 | 2280 | 90·3 | 9·18 |
| 0·046 | 138 | 2470 | 141 | 5·80 |
| 0·044 | 113 | 2490 | 123 | 5·50 |
| 0·042 | 99·4 | 2600 | 127 | 4·89 |

The junctions of the thermo-element were here, as at the calibration, covered with a layer of lampblack. It may, however, be assumed that the long-wave heat radiations used in calibrating penetrate quite deeply into the interior of the lampblack, while the cathode rays are absorbed close to its surface. If the heat conductivity of the lampblack is small compared with that of the metal of the thermo-element, it is not impossible that for the same amount of heat, the rise in temperature of the junctions under the influence of the cathode rays may be smaller than at the calibration. The lampblack was therefore removed, and in fact the value of $iV/Q$ was thereby diminished.*

The following measurements were next made after removal of the lampblack:

TABLE II.

| Pressure. | $i \cdot 10^7$ Amp. | $V$ | $Q \cdot 10^5$ gr.-cal. | $iV/Q$. |
|---|---|---|---|---|
| 0·046 | 180 | 3100 | 412 | 3·25 |
| 0·050 | 175 | 3100 | 397 | 3·28 |

TABLE III.

| Pressure. | $i \cdot 10^7$ Amp. | V | $Q \cdot 10^5$ gr.-cal. | $iV/Q$. |
|---|---|---|---|---|
| 0·043 | 122 | 3150 | 331 | 2·80 |
| 0·029 | 116 | 3500 | 416 | 2·34 |
| 0·026 | 100 | 3620 | 416 | 2·09 |
| 0·025 | 65·4 | 3820 | 309 | 1·94 |
| 0·022 | 61·7 | 4070 | 344 | 1·75 |

* This diminution no doubt comes in part as described above from the change in constant of the thermo-element after removal of the lampblack, also perhaps partly from the altered reflection of the cathode rays.

It is to be noted that in Table III as also in Table I, *the measured value of* $iV/Q$ *decreases with decreasing pressure and cathode-current.*

In order to investigate this relation more closely, a series of observations was made, varying pressure and cathode-current within as wide limits as possible. The cathode-current could be altered either by changing the number of accumulator cells, or by varying the cadmium-iodide resistance. Owing to the evolution of occluded gases from the cathode and its gradual discoloration, causing sudden irregularities in potential, it was impossible to get a perfectly consistent set of readings. Still in general it was evident that the ratio $iV/Q$ diminished with decreasing $i$, at first rapidly, then more slowly. At high pressures ($>0{\cdot}05^{mm}$), the ratio seemed to depend also upon the pressure; but when the pressure had sunk below $0{\cdot}03^{mm}$, the drift was hardly preceptible.

These results led to the supposition that beside the cathode rays, a fraction of the discharge current also was conducted from the cathode to the thermo-element; for as J. J. Thomson* has shown, the portion of gas transversed by the rays becomes a relatively good conductor, except at very low pressures. This supposition was confirmed by inserting a battery between $c$ (fig. 1) and the earth, thereby charging thermo-element and Faraday cylinder to a positive or negative potential $v$.† This cannot affect the true value of the ratio $iV/Q$ as long as $V$ denotes the difference of potential between cathode and thermo-element; but the supposed disturbing current must grow stronger or weaker according as $v$ is made positive or negative.

The following table shows how the apparent value of $iV/Q$ was correspondingly increased or diminished according to the sign of $v$.

| Pressure. | $v$ | $V$ | $i\cdot10^7$ Amp. | $Q\cdot10^5$ g-cal. | $iV/Q$. |
|---|---|---|---|---|---|
| 0·050 | +70 | 4050 | 3·54 | 34·1 | 1·01 |
| 0·050 | 0 | 3980 | 2·64 | 30·2 | 0·84 |
| 0·050 | −70 | 3910 | 2·29 | 30·5 | 0·71 |

The potential of the cathode as measured on the electrometer is here $V-v$; as in all measurements, $i$ denotes the observed sum of cathode- and disturbing currents.

The variations in the value of $Q$ result from the fact that the path of the rays was visibly altered while the thermo-element was charged.

* J. J. Thomson, Phil. Mag., xliv, p. 293, 1897.

† The cylinder was here connected with the point $c$. Owing to incomplete insulation between thermo-element and cylinder it was not practicable to connect the latter directly to earth.

The cathode-current is here only about 1/30 as intense as in Tables II and III, hence the value of $iV/Q$ is also much smaller. The extremely small value of $iV/Q$ when the charge is negative is explained as follows: owing to the conductivity of the path of the rays, a weak current finds its way from the battery used in charging the thermo-element, along this path to the anode. This current is opposed to the cathode-current, thereby reducing the apparent value of the ratio $iV/Q$. When the thermo-element is positively charged, the ratio is on the other hand greatly increased.

Measurements similar to the above, made at a pressure of $0{\cdot}012^{mm}$, showed that charging the thermo-element no longer had any influence upon the value of the ratio. These observations on the conductivity of the cathode rays agree well with those of Starke* and Thomson.†

The attempt was also made to intercept the disturbing current by means of a grating of several fine wires laid over the opening of the Faraday cylinder. This was, however, of no practical assistance, as even at high pressures the effect was very slight.

The results that have been given show that the observed value of $iV/Q$ was in general too large. The disturbing current was at times greater than the cathode-current itself, but it was impossible to measure directly its absolute value. It therefore remained to establish the lower limit of the ratio. For this purpose a series of 46 observations was selected, having a range of pressure from $0{\cdot}01$ to $0{\cdot}05^{mm}$, of potential from 2400 to 5400 volts, and of cathode-current from $40{\cdot}10^{-7}$ to $0{\cdot}23{\cdot}10^{-7}$ amp. When arranged in order of decreasing cathode-current, the values of $iV/Q$ showed great irregularities, since the order was without regard to pressure and other conditions. Still a distinct drift in the ratio was evident, especially when the observations were divided into five groups and the average values taken:

| Pressure. | $i{\cdot}10^7$ Amp. | $iV/Q$ |
|---|---|---|
| $0{\cdot}041$ | $19{\cdot}6$ | $1{\cdot}32$ |
| $0{\cdot}035$ | $7{\cdot}41$ | $0{\cdot}97$ |
| $0{\cdot}026$ | $4{\cdot}29$ | $0{\cdot}85$ |
| $0{\cdot}033$ | $2{\cdot}02$ | $0{\cdot}84$ |
| $0{\cdot}023$ | $0{\cdot}49$ | $0{\cdot}83$ |

From this it is evident that when the cathode-current decreases to the fortieth part of its original value, the ratio $iV/Q$ is changed by only 38 per cent. This at least makes it seem

* H. Starke, Wied. Ann., lxvi, p. 52, 1899.
† J. J. Thomson, Phil. Mag, xliv, p. 293, 1897.

probable that eq. (4*a*) is approximately correct, although the limiting value of the ratio is considerably smaller than unity. Still owing to the sources of error in the use of the thermo-element, no great dependence can be placed upon absolute values. It was therefore determined to measure the energy $Q$ in a surer manner, by Kurlbaum's bolometric method.*

*Observations with Bolometer.*

A surface-bolometer forms one arm of a Wheatstone bridge; suppose the bridge balanced, and a current of intensity $I_1$ flowing through the bolometer. Let the resistance of the bolometer under these conditions be $w$. If now an amount of heat $Q$ per second be supplied by the cathode rays to the bolometer, the galvanometer in the bridge will suffer a certain deflection. Suppose the same deflection caused by increasing $I_1$ to $I_2$, the cathode rays no longer acting. Then from Kurlbaum's formula,

$$Q = w \cdot \frac{I_2}{I_1}(I_2^2 - I_1^2) \text{ watts},$$

where $I$ and $w$ are expressed in amperes and ohms respectively.

If the four bridge resistances are equal, then $I = \frac{1}{2}c$, where $c$ is the current in the battery branch, and

$$Q = \tfrac{1}{4}w \cdot \frac{c_2}{c_1}(c_2^2 - c_1^2) \text{ watts}.$$

As it was not practicable to make both deflections exactly equal, the following method was adopted:

1. galv. defl. $a_1$ with current $c_1$, rays falling.
2. " " $a_2$ " " $c_2$, " deflected.

We thus get the following equation:

$$Q = \tfrac{1}{4}w \frac{a_1}{a_2} \frac{c_2}{c_1}(c_2^2 - c_1^2)$$

The thermo-element formerly used ($S$, fig. 1) was replaced by a bolometer, whose terminals were led out through the plate $P$. The bolometer was made after Lummer and Kurlbaum's process,† with a few modifications. In the first observations it consisted of a platinum foil about $0{\cdot}001^{mm}$ thick, mounted with mica insulation upon a brass frame. The form is shown in $B$ (fig. 2). Care was taken that the entire bolometric resistance should be reached by the rays; also that all cathode rays entering the Faraday cylinder that did not strike

* F. Kurlbaum, Wied. Ann., lxv, p. 746, 1898.
† O. Lummer and F. Kurlbaum, Wied. Ann., xlvi, p. 204, 1892.

the bolometer, should give up their charge to earth through the metallic frame. Although the density of the rays is not perfectly uniform throughout the bundle, still it can be assumed that the distribution of temperature in the thin bolometric foil under the influence of the rays and of the electric current is practically identical.* The silver was not dissolved away from the platinum-silver foil until the bolometer had been mounted.

2

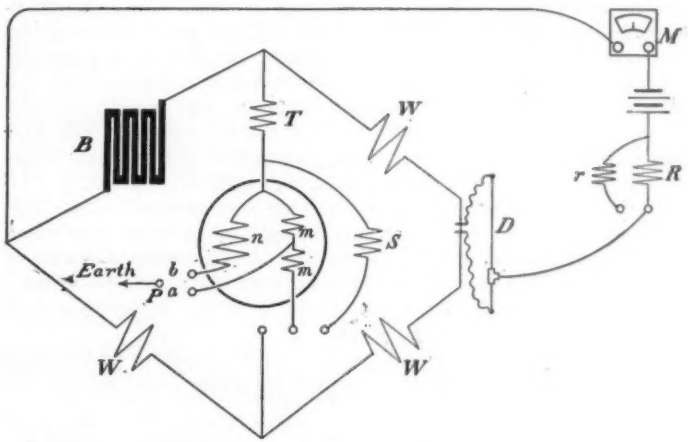



Fig. 2 shows the arrangement of the bridge. The current-intensity $i$ in the battery branch was measured by means of the ampere-meter $M$. Shunting the resistance $r$ parallel to $R$ increased the current from $i_1$ to $i_2$ and gave an accurate means for measuring the increase. A Thomson galvanometer of du Bois-Rubens type was employed. For the thermal measurements two 20-ohm coils $mm$ were used; in order to get rid of the cathode-current, a point between the two coils was led to earth (contact $a$, fig. 2) and the resistance $T$ so chosen that with battery disconnected the cathode-current caused no deflection of the galvanometer. Two 2000-ohm coils $n$ served to measure the cathode-current, by closing the contact $b$, while $a$ remained open.

$S$ is a shunt for reducing the sensitiveness of the galvanometer when necessary. The bridge resistances were balanced by means of the sliding contacts at $D$. The manganin wire resistances $W$ were as nearly equal to the bolometric resistance

*F. Kurlbaum, Wied. Ann., lxv, p. 755, 1898.

as possible, but small discrepancies were always taken into account. It was necessary to use great care in insulating the entire circuit from earth.

The bolometer was found to be much more sensitive than the thermo-element, although its effective surface was smaller. The source of error from gas-evolution was also less serious, owing to the rapidity with which observations could be made.

The process of etching and washing such small bolometers is somewhat complicated when a metallic frame is used, as the latter has to be protected by a coating of wax, which is afterwards dissolved away. Thus it is difficult to avoid straining the delicate platinum strips. This may become a very serious source of error, as it is impossible to know the extent of the injury. Moreover, a brownish deposit was nearly always formed upon the strips, probably from some action of the acid used to dissolve the silver, upon impurities in the wax. This may in some way have caused a further source of error.

Four different bolometers with brass frames were used. The results are briefly given below, though in at least two cases great irregularities occur. It was not until a frame of slate had been made that reliable observations were obtained (see below).

*Bolometer I.* Eleven strips, $11{\cdot}5 \times 0{\cdot}66^{mm}$. Resistance $w$ at room temperature $= 26{\cdot}21$ ohms.

The observations were all made at high pressures; the ratio $iV/Q$ is therefore chiefly dependent upon the pressure and not upon the cathode-current.

| Pressure. | $i \cdot 10^7$ Amp. | $V$ | $Q \cdot 10^5$ Watt. | $iV/Q$. |
|---|---|---|---|---|
| 0·116 | 18·0 | 2590 | 213 | 2·21 |
| 0·113 | 12·3 | 2610 | 140 | 2·28 |
| 0·064 | 22·3 | 4090 | 541 | 1·69 |
| 0·055 | 13·7 | 4210 | 376 | 1·53 |

*Bolometer II.* Nine strips, $11{\cdot}5 \times 1{\cdot}0^{mm}$. $w = 15{\cdot}74$ ohms.

An influence machine was used instead of the battery as source of discharge. As the range of values of $i$ is not great, only the average values are here given: $i = 1{\cdot}40 \cdot 10^{-7}$ amp.; pres. $= 0{\cdot}020^{mm}$; $iV/Q = 0{\cdot}81$.

*Bolometer III.* Seven strips, $11{\cdot}5 \times 1{\cdot}3^{mm}$. $w = 8{\cdot}75$ ohms.

A battery of 30 cells was so arranged that it could be connected at will between $P$ (fig. 2) and the earth. This raised the bolometer and of course the entire bridge to the potential of the battery. The Faraday cylinder was kept in contact with $P$. Readings were taken with the bolometer alternately at 0 and +60 volts.

From the table it is evident that as in the case of the thermo-element, charging the bolometer to a certain potential increases the ratio $iV/Q$ to a greater extent, the stronger the cathode-current, that is, the greater the conductivity of the gas.

| Pressure. | $v$ | $i \cdot 10^7$ | $V$ | $Q \cdot 10^5$ | $iV/Q$. |
|---|---|---|---|---|---|
| 0·033 | 0 | 5·30 | 3130 | 106 | 1·57 |
| | +60 | 7·20 | 3090 | 119 | 1·91 |
| 0·028 | 0 | 2·10 | 4320 | 80·8 | 1·12 |
| | +60 | 3·23 | 4200 | 113 | 1·20 |
| 0·029 | 0 | 1·96 | 5150 | 75·5 | 1·33 |
| | +60 | 4·91 | 4960 | 154 | 1·58 |
| 0·030 | 0 | 1·90 | 4230 | 67·5 | 1·19 |
| | +60 | 2·80 | 4130 | 88·5 | 1·31 |
| 0·030 | 0 | 0·54 | 3910 | 20·8 | 1·02 |
| | +60 | 0·67 | 3880 | 25·3 | 1·02 |
| 0·031 | 0 | 0·28 | 4220 | 11·9 | 0·98 |
| | +60 | 0·56 | 3900 | 21·9 | 1·01 |

*Bolometer IV.* Seven strips, $11 \cdot 5 \times 1 \cdot 3^{mm}$. $w = 9 \cdot 20$ ohms. Values of the ratio were irregular, but the averages from three groups of observations are here given:

| Pressure. | $i \cdot 10^7$ Amp. | $iV/Q$. |
|---|---|---|
| 0·070 | 9·43 | 0·81 |
| 0·040 | 11·48 | 0·76 |
| 0·023 | 0·18 | 0·72 |

As with Bol. I, the ratio at high pressures seems dependent upon the pressure alone. In the third group the cathode-current was diminished by increasing the cadmium iodide resistance.

These results are of only relative importance except as they indicate that the absolute value of $iV/Q$ is somewhat less than 1.

A fifth bolometer was therefore made and mounted after the Kurlbaum process upon a slate frame. After the silver had been dissolved from the foil, the strips looked perfectly clean and seemed free from strains. In order to keep the cathode rays from the slate, a small brass diaphragm was placed close over the bolometer, with a square opening of the same size as the bolometer surface.

*Bolometer V.* Seven strips, $7 \times 0 \cdot 73^{mm}$. $w = 8 \cdot 72$ ohms. The following observations were taken:

| Pressure. | $i \cdot 10^7$ | $V$ | $Q \cdot 10^5$ | $iV/Q$. |
|---|---|---|---|---|
| 0·038 | 6·10 | 2270 | 76·9 | 1·80 |
| 0·061 | 5·00 | 2690 | 82·3 | 1·58 |
| 0·035 | 4·80 | 3480 | 149 | 1·12 |
| 0·024 | 2·26 | 3770 | 85·5 | 1·00 |
| 0·024 | 2·09 | 3560 | 81·2 | 0·92 |
| 0·030 | 1·69 | 4460 | 92·6 | 0·81 |
| 0·022 | 1·36 | 3730 | 58·0 | 0·87 |
| 0·032 | 1·09 | 3740 | 50·4 | 0·81 |
| 0·032 | 1·06 | 3750 | 47 9 | 0·83 |
| 0·028 | 0·50 | 3900 | 23·6 | 0·83 |
| 0·026 | 0·255 | 4740 | 14·5 | 0·83 |
| 0·023 | 0·040 | 4800 | 2·29 | 0·84 |

This bolometer was apparently free from the faults of its predecessors: therefore only the usual errors of observation need be considered, especially that arising from the evolution of gas. This error can hardly have amounted to more than 3 per cent with weak cathode-current; hence it follows from the last table that the true value of the ratio $iV/Q$ lies between 0·80 and 0·86.

Since the bolometer foil was only $0{\cdot}001^{mm}$ thick, the question arises whether an appreciable part of the rays can have penetrated through to the other side. In this case it might easily happen that the particles on passing through would lose a part of their energy while retaining their charge. McClelland* and Wien† have shown that cathode rays after traversing an aluminium window carry a negative charge; but Lenard did not succeed by means of a thermo-element in detecting any heating effect.‡ Still if we assume according to Lenard that for solids the quotient of absorptive-power divided by density = 3200,§ we find from his formula that not more than 1 per cent of the rays can have passed through the bolometric foil used. This can have had practically no effect upon the ratio under discussion.

### *Conclusion.*

It only remains to compare the limiting value of the ratio as experimentally determined, with the equation (4*a*)

$$\frac{iV}{Q} = \frac{i-r}{1-rr'},$$

where $r$ denotes the reflected part of the rays, while upon reflection the rays lose their energy in the ratio $r' : 1$.

Starke‖ has found that platinum reflects about 40 per cent of the rays. Assuming, therefore, that for the bolometer, $r = 0{\cdot}4$, we find that when $iV/Q = 0{\cdot}83$, $r' : 0{\cdot}7$.

This result is in contradiction with the observations of Merritt already referred to. The latter are unfortunately not above criticism, as the author himself admits. Merritt compared the deflectibility of direct and reflected rays by observing the phosphorescence on the walls of the tube. It is hardly to be supposed that the spot from the reflected ray can have been even approximately as distinct as that from the

* J. A. McClelland, Proc. Roy. Soc., lxi, p. 227, 1897.

† W. Wien, Verh. Phys. Ges. Berlin, xvi, p. 165, 1897.

‡ Ph. Lenard, Wied. Ann., li, p. 239, 1894. This experiment was, however, performed in air at ordinary pressure, which rapidly absorbs the energy of the cathode rays.

§ Ph. Lenard, Wied. Ann., lvi, p. 274, 1895.

‖ H. Starke, Wied., lvi, p. 58, 1899.

direct; moreover, since an induction coil was used as source of discharge, one would expect the formation of a "magnetic spectrum,"* which would greatly complicate the appearance of both spots. Thus it is easy to see that a systematic error may have crept into the results.

Whether such an error can have been great enough to give the value $r' = 1$ instead of $r' = 0{\cdot}7$ is, of course, not certain; but it may be added that the energy of the cathode rays is proportional to the square of their deflectibility, hence an error of $n$ per cent in the measurement of the deflection would correspond to an error of $2n$ per cent in the energy. In any case it is desirable to determine both the deflectibility and the energy of reflected cathode rays by as accurate a method as possible.

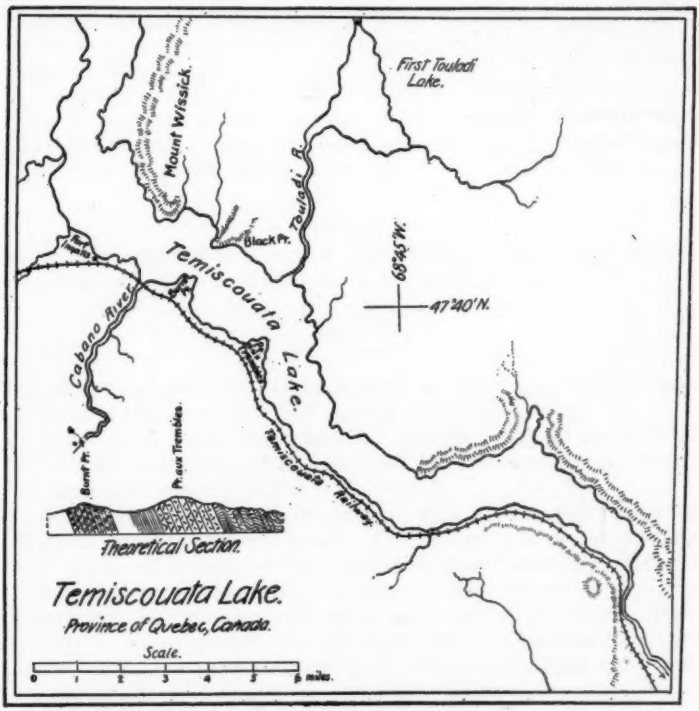
My thanks are due to Prof. Warburg for his kind advice and assistance during this investigation.

* K. Birkeland, Comptes Rendus, cxxiii, p. 492, 1896.

Providence, R. I., May 5, 1900.

ART. II. — *Volcanic Rocks from Temiscouata Lake, Quebec;* by HERBERT E. GREGORY.

TEMISCOUATA LAKE was explored by the early geologists of Canada, and Logan reported* the presence at Pointe aux Trembles of 'tough, green sandstone, with pebbles of metamorphic rock.' A survey of the region was made by Bailey and McInnes in 1886–87, and the presence of volcanic rocks noted. Their report in reference to these rocks reads as follows: "It is important to notice in connection with the Pointe aux Trembles sandstones the evidence which they appear to afford of contemporaneous volcanic activity. This is, perhaps,




partly indicated by the color of the rock, which varies from green to red and purple, but is more clearly seen in the abundance of epidote with which the rock is charged and in places

* Geology of Canada, 1863, p. 423.

its somewhat amygdaloidal aspect."* During the summer of 1897, the region was studied by Prof. H. S. Williams, and the specimens then collected were turned over to the writer for examination. The outcrops visited extend along the lake for a distance of 20 miles, as shown on the accompanying map.

*Mount Wissick.*—The rocks examined from Mt. Wissick and the east shore of the lake are fossiliferous limestones, sandstones and shales, without admixture of volcanic materials. The shales and sandstones do not differ from similar rocks found elsewhere. The arenaceous limestone in places is separated into hexagonal prisms, probably from shrinkage, and appears as if composed of vertical columns with quite regular outline. The thin layers of limestone in the slates at the north of Mt. Wissick show under the microscope well-defined oolitic structure in which the little spheres are broken by numerous minute faults.

*West Shore.*—The section on the West Shore extends from Burnt Point, below Fort Ingalls, to the outlet of the lake.

At Burnt Point the rocks are coarse conglomerates made up of materials not much water worn, and show evidence of rapid deposition. Slates and limestones form the most abundant pebbles, and occasionally attain a diameter of 1–2 feet. The total thickness of the conglomerate at this point is about 1000′, but such great thickness of the beds is reported to be quite local. Succeeding the Burnt Point conglomerate, to the south, occur thin-bedded shales and sandstones, which contain fossils of Niagara age.†

At Point aux Trembles, the rocks, both along the railroad and on the lake shore, appear at first sight to be greenish sandstones and coarse brown conglomerates. They are interstratified with the other beds of the region, and have practically the same dip and strike. A closer examination, however, shows them to be volcanic. The finer, more sandy beds, contain quantities of volcanic ash, and the coarser ones are conglomerates of typical andesitic fragments, with scarcely any foreign material. Parts of the rock contain very prominent rounded fragments of amygdaloidal andesite. As with the volcanics of northern Maine,‡ so here the gradation from the sandstones of the region to pure volcanic material can be traced, and like the Maine breccias and tuffs, these rocks show more or less rounding of their pebbles and sorting by wa er. It is believed that the volcanic vents were near some body of water, and that the material fell in or near the water and received a limited amount of wearing before final consolidation.

* Geol. Survey of Canada—Annual Report, 1887, p. 33M.
† Geol. Survey Canada, Annual Report, 1887, p. 33M.
‡ U. S. G. S. Bulletin 165.

From Point aux Trembles to the foot of the lake—a distance of about 10 miles—the rocks which outcrop are slates and impure sandstones with rare tufaceous material. In places the beds are much folded and traversed by faults of small displacement.

*Petrography.*

The ordinary stratified rocks of the region present no peculiarities which require detailed description. The volcanic series consists of fine tuff and coarse amygdaloidal conglomerate or breccia.

*Fine Tuff.*—The fine tuff appears in the hand specimen as a dense bluish-grey sandstone in beds a few feet in thickness. Under the microscope its true character is revealed, and it is found to consist of tiny fragments of andesite, broken crystals of plagioclase and olivine, and areas of devitrified glass with rare quartz grains and biotite shreds. The andesite has a hyalopilitic groundmass, which varies in amount of glass, so that some fragments appear to be practically all glass with only a few scattered laths of plagioclase. The larger crystals of andesine have albite twinning and are largely kaolinized. The olivines are represented in the slide by areas of serpentine with characteristic outlines and cleavages shown by dotted ore grains. Iron ore is sprinkled quite generally through the section.

*Volcanic Conglomerate.*—The volcanic conglomerate consists of subangular pebbles of andesite and amygdaloidal andesitic bombs, embedded in a finer matrix of red and green grains of the same material. The pebbles range in size from $\frac{1}{2}$ inch to 6 inches in diameter, and show in the hand specimen phenocrysts of plagioclase, and occasionally epidote and augite. The embedded bombs form a conspicuous feature of the rock. They are quite spherical and are distinctly different in appearance from the matrix. Amygdules, about the size of bird shot, make up fully one-half of the bomb and are filled with green balls of chlorite—rarely with calcite. Some of the larger amygdules are seen to be occupied by chalcedony inside the chlorite lining.

*Microscopic Examination.*—The microscope shows the general matrix of this coarse type to consist of crystals of feldspar, pyroxene and olivine, and fragments of andesite, devitrified glass, and jasper. Iron dust, a small amount of calcite, and a few shreds of biotite, are also present. The feldspar crystals consist of a few orthoclases, and many rather small andesines, with albite and carlsbad twins. The pyroxene crystals are represented only by their outline, in a base peppered with iron dust. The olivines are fragmentary crystals, and largely replaced by serpentine and iron. The bulk of the sec-

tions examined is formed of fragments of pyroxene-andesite of a type sparingly porphyritic with small stout phenocrysts set in a groundmass, having in some places a glassy base, in others being made up almost entirely of ragged feldspar microlites, arranged with flow structure. The fragments of devitrified glass present show occasional cusps, which represent expanded steam cavities. No close line, however, can be drawn between the fragments of glass and the fragments of andesite containing a few feldspar microlites in a glassy base. The dark-red iron dust is not generally distributed through the rock, but is present along the cracks of the olivine crystals, and it also gives color to the glassy fragments.

*The Amygdaloidal Bombs.*—The section cut from one of the amygdaloidal bombs reveals the composition and structure of an extrusive basic andesite. The minerals present as phenocrysts are plagioclase, pyroxene, olivine and iron ore, with infiltrated quartz and calcite in the amygdules. There is also a considerable development of minerals of the chlorite group, perhaps largely delessite. The plagioclases are short, rather square crystals with ragged ends and strongly-marked albite and pericline twinning. Many of them are bent and curved and irregularly broken. In composition they are between andesine and labradorite. Augite occurs as stout crystals always partly decayed and replaced by chlorite or epidote, or rarely by calcite. Olivine crystals are about as abundant as augite and show their characteristic parting along cracks now filled with iron. Serpentine has generally replaced the olivine. Iron ore occurs in a few ragged grains. The groundmass is of feldspar microlites usually untwinned and with little evidence of flowage. The structure was hyalopilitic, but the glass filling the interstices is devitrified and stained brown with iron. The steam cavities now filled and converted into amygdules, though very abundant, have exerted little influence on the arrangement of the feldspars in the groundmass—a fact which suggests that these cavities formed in part before any crystallization of feldspars had occurred.

All the amygdaloidal cavities are filled with secondary products which have a uniform arrangement. They are lined with a coating of a malachite-green mineral of the chlorite group, arranged in radial forms. Most of the smaller cavities are completely filled with this substance and appear on the rock surface as embedded green pellets. The larger cavities have the chlorite lining fractured, and fragments of it have floated in toward the center, leaving means of access for later infiltrations. Similar phenomena have been observed in certain

volcanic rocks in Maine.* The inside filling of the amygdules is silica or rarely calcite. The material next to the chlorite lining is chalcedony, with well-developed mammillary structure. The center of the cavity is a mass of quartz grains separated from the chalcedony by a definite boundary. It thus appears that the amygdules were filled by three or four successive periods of infiltration.

*Summary.*—While the mere description of these rocks and the determination of their volcanic origin is, in itself, chiefly of local interest, these facts have, however, important bearings on the general geological history of the Atlantic coastal region. That they are interbedded with Niagara sediments helps to determine the time when wide-spread volcanic activity gave rise to the numerous small areas of tuffs and lavas in the Maine-Quebec region, while this fact throws additional light on the physical conditions obtaining in that period. And finally, the recognition of so much distinctly contemporaneous volcanic material in well-bedded sediments affords another plea for the study of the sedimentaries by microscopic analysis.

* U. S. G. S. Bulletin 165, Plate XIV.

Yale University, New Haven, Conn., March, 1900.

ART. III.—*On the Interpretation of Mineral Analyses: a Criticism of recent Articles on the Constitution of Tourmaline;* by S. L. PENFIELD.

ABOUT eighteen months have elapsed since H. W. Foote and the author published in this Journal* a joint article on the chemical composition of tourmaline. Since that time two articles have appeared, presenting views differing from one another and from those of Foote and the author; one on the Constitution of Tourmaline, by Prof. F. W. Clarke† of Washington, the other *Über das Mischungsgesetz der Turmaline*, by Prof. G. Tschermak‡ of Vienna.

In order to discuss the views presented in these articles it is desirable to carefully consider some facts concerning chemical analyses. In the first place, a perfect chemical analysis cannot be made. There are, to be sure, a very few analytical processes for the determination of single constituents, which, when carefully executed, can be relied upon to give results varying less than 0·01 per cent from the theory; but when it comes to mineral analysis, necessitating the splitting up of a complex body and the determination of a number of constituents, such accuracy cannot be attained. In making a mineral analysis, one seldom feels confident that all determinations are correct, even within 0·25 per cent of the truth, although if duplicate analyses are made, it is expected that, for the majority of the constituents at least, the two determinations will agree within 0·10 or 0·20 per cent of one another. At times, of course, depending upon the difficulty of the analysis or the scarcity of available material, variations of 0·50 per cent, or even more, in duplicate determinations are not to be wondered at.

Secondly, analytical work may be of a high order, the results very accurate, and yet an analysis may not serve for the determination of a chemical formula because made on material more or less impure. The chemists of to-day have a decided advantage over those of a former generation, for the microscope enables them to study their material, select that which is best, and, if impurities cannot be avoided, to take their effect into consideration in discussing the analytical results. Then again the heavy solutions are invaluable for separating out material for analysis, and, what is considered of very great importance, for furnishing a guarantee of the purity of any given material; for if it can be stated that all of the mineral floats on a solution of a certain specific gravity and sinks when

* Vol. vii. p. 97, 1899.
† This Journal, IV, viii, p. 111, 1899.
‡ Mineralog. und Petrogr. Mitth., xix, p. 155, 1899.

the specific gravity is lowered to a trifling extent, it gives one not only great confidence in the purity of the material, but, also, it enables the investigator to present data which others can make use of in judging the character of the work.

It has been the author's privilege during the past twenty-five years to make many analyses of minerals, and to superintend the making of many more in the Sheffield Mineralogical Laboratory; also to discuss the analytical results and derive therefrom the chemical formulas of minerals, and this occasion will be taken to call attention to certain features which are regarded as most important in mineralogical investigations. In the first place, the utmost pains should be taken to secure pure material, and, if the results are to be published, the character of the material should be described so that its degree of purity can be judged by others. Secondly, if an analysis presents any especially difficult features, the method of analysis should be carefully described, and it is in almost all cases well to give at least some brief outline of the analytical methods employed. Then, too, when material is abundant, it is advisable to make analyses in duplicate, and to give all of the determinations, together with the averages. Thus the investigator has from beginning to end the satisfaction of a control over all determinations, and, if agreements are close, others can form some estimate concerning the care with which the work was executed. There are those who apparently entertain the belief that closely agreeing duplicate determinations indicate great accuracy in analytical work, but that is not necessarily the case, for in some analytical methods there is a tendency for results to come too high, in others too low, and thus duplicate determinations, made under like conditions, either with faulty methods, or with good methods improperly executed, may be uniformly high or uniformly low, agreeing with one another, and yet varying considerably from the truth. Still two closely agreeing determinations carry with them a certain weight which cannot be ignored. Thirdly, with each analysis, the quotients obtained by dividing the several constituents by their molecular or atomic weights, as the case demands, should be given, and from the quotients thus obtained the ratio between the several constituents should be determined. The ratio ought not to be given simply rounded out to the nearest whole numbers, but, taking the quotient of the most characteristic or best determined constituent as unity, the ratio should be given to the second place of decimals. *It is safe to assume that the close approximation of a ratio to whole numbers constitutes the strongest argument that can be advanced in support of the excellence of an analysis and the correctness of the derived formula.* It will seldom happen that a ratio approximates to whole numbers merely as a matter of accident. Provided the

compound is a simple one, instead of giving the ratio, an excellent method is to give the calculated composition, which can then be compared directly with the results of the analysis. Lastly, for determining a formula one or two good analyses are of more value than many indifferent ones, hence it will often prove best to make new analyses on material of unquestioned purity. This may be done not wholly with the idea that the new analyses are better than those made by other investigators, but, knowing all about the quality of the material and the working of the analyses, it will be possible to exercise better judgment in summing up the results of the investigation, and to present with greater force the arguments needed in support of the proposed formula.

Turning now to the consideration of tourmaline, two new analyses were made by Foote and the author, upon material of ideal purity and with the use of most carefully studied methods. The results need not be repeated here, but it will be stated that, with the exception of a single water determination, all constituents were determined in duplicate; that in twenty out of a total of twenty-three instances, the discrepancy between duplicate determinations did not exceed 0·10 per cent; and that the maximum variation in the remaining three instances was 0·18 per cent. The single water determination which was not duplicated was controlled by a closely agreeing estimation of loss on ignition. In working out the ratios from these analyses, the method was adopted of calculating for the metals their equivalent of hydrogen, including fluorine with hydrogen, since tourmaline contains hydroxyl with which fluorine is isomorphous. Thus the ratio was found between $SiO_2$, $B_2O_3$, and Total Hydrogen, from which the empirical formula of the tourmaline acid was derived. For the sake of the present discussion the ratios will be repeated in two forms: with one-fourth of the $SiO_2$ as unity and also with one-twentieth of the Total Hydrogen as unity. This latter method has been here adopted, because a few relations can be brought out better in the discussion by so doing. The ratios of the two analyses are as follows:

| | $SiO_2$ | $B_2O_3$ | Total H. | $SiO_2$ | $B_2O_3$ | Total H. |
|---|---|---|---|---|---|---|
| De Kalb | 4·00 | 1·01 | 19·90 | 4·02 | 1·01 | 20·00 |
| Haddam Neck | 4·00 | 1·02 | 19·98 | 4·00 | 1·02 | 20·00 |

These ratios approximate *very closely* to the whole numbers 4:1:20; such close approximations, in fact, are seldom obtained, and cannot in these two instances be regarded merely as matters of accident; they are the reward, rather, of careful analytical work on material of unquestionable purity. As soon as the ratios were worked out, it was seen at once that at least one important key to the solution of the tourmaline problem had

at last been found: *the empirical formula of the tourmaline acid must be* $H_{20}B_2Si_4O_{21}$.

And now, for the sake of the discussion, some space will be devoted to the ratios derived from the analyses of Riggs, and Jannasch and Kalb. These have already been given by Foote and the author* with $\frac{1}{4}$ $SiO_2$ as unity, and are now repeated, together with the ratios derived by taking $\frac{1}{20}$ Total Hydrogen as unity. They have moreover been arranged in series, commencing with the closest approximation to 4 : 20 between $SiO_2$ and Total Hydrogen, and proceeding to the maximum deviation from this ratio.

TOURMALINE RATIOS DERIVED FROM THE ANALYSES OF RIGGS.

| No. | No. Dana. | $SiO_2$ : $B_2O_3$ : Total H. | $SiO_2$ : $B_2O_3$ : Total H. |
|---|---|---|---|
| 1. | 43. | 4·00 : 0·94 : 20·03 | 3·99 : 0 94 : 20·00 |
| 2. | 45. | 4·00 : 0·95 : 20·03 | 3·99 : 0·95 : 20·00 |
| 3. | 48. | 4·00 : 1·01 : 20·06 | 3·99 : 1·00 : 20·00 |
| 4. | 47. | 4·00 : 0·98 : 20·08 | 3.98 : 0·97 : 20·00 |
| 5. | 52. | 4·00 : 0·94 : 20·11 | 3·98 : 0·93 : 20·00 |
| 6. | 49. | 4·00 : 1·01 : 20·12 | 3·97 : 1·00 : 20·00 |
| 7. | 36. | 4·00 : 0·90 : 20·2 | 3·96 : 0·89 : 20·00 |
| 8. | 44. | 4·00 : 0·88 : 20·2 | 3·96 : 0·87 : 20·00 |
| 9. | 46. | 4·00 : 0·96 : 20·2 | 3·96 : 0·95 : 20·00 |
| 10. | 42. | 4·00 : 0·97 : 19·8 | 4·04 : 0·98 : 20·00 |
| 11. | 54. | 4·00 : 0·98 : 19·8 | 4·04 : 0·99 : 20·00 |
| 12. | 39. | 4·00 : 0·94 : 19·7 | 4·06 : 0·95 : 20·00 |
| 13. | 41. | 4·00 : 0·92 : 19·7 | 4·06 : 0.93 : 20·00 |
| 14. | 51. | 4·00 : 0·91 : 19·6 | 4·08 : 0.93 : 20·00 |
| 15. | 37. | 4·00 : 0·93 : 20·5 | 3·90 : 0·91 : 20·00 |
| 16. | 38. | 4·00 : 0·92 : 19·5 | 4·10 : 0·93 : 20·00 |
| 17. | 55. | 4·00 : 1·01 : 20·6 | 3·88 : 0·98 : 20·00 |
| 18. | 40. | 4·00 : 0·96 : 19·3 | 4·14 : 1·00 : 20·00 |
| 19. | 50. | 4·00 : 0·98 : 19·2 | 4·16 : 1·02 : 20·00 |
| 20. | 53. | 4·00 : 0·97 : 18·9 | 4·23 : 1·00 : 20·00 |
| Average | | 4·00 : 0·95 : 19·88 | 4·02 : 0·96 : 20·00 |

TOURMALINE RATIOS DERIVED FROM THE ANALYSES OF JANNASCH AND KALB.

| No. | No. Dana. | $SiO_2$ : $B_2O_3$ : Total H. | $SiO_2$ : $B_2O_3$ : Total H. |
|---|---|---|---|
| 1. | 62. | 4·00 : 0·80 : 20·00 | 4·00 : 0·80 : 20·00 |
| 2. | 64. | 4·00 : 0·84 : 20·01 | 4·00 : 0·84 : 20·00 |
| 3. | 61. | 4·00 : 0 95 : 20·2 | 3·96 : 0·94 : 20·00 |
| 4. | 57. | 4·00 : 0·99 : 19·8 | 4·04 : 1·00 : 20·00 |
| 5. | 56. | 4·00 : 0·96 : 19·7 | 4·06 : 0·97 : 20·00 |
| 6. | 63. | 4·00 : 0·98 : 19·7 | 4·06 : 0·99 : 20·00 |
| 7. | 58. | 4·00 : 0·95 : 20·4 | 3·92 : 0·93 : 20·00 |
| 8. | 60. | 4·00 : 0·88 : 20·4 | 3·92 : 0·86 : 20·00 |
| 9. | 59. | 4·00 : 0·92 : 18·8 | 4·25 : 0·98 : 20·00 |
| Average | | 4·00 : 0·92 : 19·9 | 4·02 : 0·93 : 20·00 |

* Loc. cit., pp. 114 and 115.

Before entering upon the discussion of these ratios, let it be understood that the analysis of tourmaline is one of the difficult problems of analytical chemistry, and although Riggs made duplicate and often triplicate determinations of $B_2O_3$ and $H_2O$ in almost all cases, and duplicated somewhat more than half of his determinations of $SiO_2$ and F, only single determinations of other constituents are recorded in his paper, while Jannasch and Kalb record only single determinations. Also it is to be borne in mind that although both Riggs and Jannasch and Kalb undoubtedly used carefully selected tourmaline fragments for analysis,* still there is nothing to indicate that slight amounts of foreign materials might not have been present in some of the specimens analyzed. Keeping these facts then well in mind, let us examine the ratios as presented in the foregoing tables. It is granted that the ratios are not exactly 4:1:20, and to get *exact ratios* from mineral analyses is not to be expected, but the close approximation to 4:1:20 in the case of the two analyses by Foote and the author, of sixteen out of the twenty analyses by Riggs, and of eight out of the nine analyses by Jannasch and Kalb, *constitutes an overwhelming amount of evidence in support of the empirical formula of the tourmaline acid,* $H_{20}B_2Si_4O_{21}$. It is safe to state that there does not exist a series of thirty silicate analyses of any one mineral yielding ratios which approximate so closely to whole numbers as the tourmaline analyses referred to above. That some analyses fail to yield a ratio as close to rational numbers as desired, reflects discredit neither upon the analyst nor upon the character of his work, for the material for analysis might not in all cases have been pure. Take, for example, No. 17 of the series of Riggs, brown tourmaline from Hamburg, N. J., occurring in calcite. The ratio of $SiO_2$: Total Hydrogen = 4:20·6. Evidently the bases are too high, and this particular analysis is peculiar in that it shows 5·09 per cent CaO, while the next highest percentage of CaO recorded is 3·70. The material might well have contained some calcite, either as small included nodules, or as an infiltration along cracks, and if the amount of calcite be assumed as 1·78 per cent, equivalent to 1 per cent CaO, the analysis would add up to 100·82, which is not too high for such a complicated substance, and the ratio of $SiO_2$: Total Hydrogen would become 4·00: 20·3 or 3·94: 20·00. To assume that the Hamburg material probably contained some calcite seems far more reasonable than to speculate, as Prof. Clark does, upon some complex formula especially adapted to suit this particular analysis. Again, Nos. 18, 19, and 20 of Riggs, and 9 of Jannasch and Kalb indicate either

* Compare foot-note, this Journal, IV, vii, p. 115, 1899.

that the amount of base is low, $SiO_2$ being assumed as practically correct, or, what is far more likely, that the amount of $SiO_2$ is too high, as seen best when one-twentieth of the Total Hydrogen is taken as unity. Does the high silica ratio indicate that for these special cases a new type of tourmaline formula is needed, or is it not simpler to assume that the material from which these analyses were made might possibly have contained a little quartz or other silicate as impurity? It would take not over two per cent of quartz as an impurity to bring about the extreme amount of variation from the ratio 4:20 recorded in the foregoing tables.

Both Clarke and Tschermak seem to place implicit confidence in *all* of the recent tourmaline analyses: they seem to regard them as perfect, and the material analyzed as necessarily pure; consequently they try to devise formulas or expressions (how complicated they are will be shown) to suit all of the analyses. Clarke states that a formula in order to be satisfactory "must adequately express the composition of the compound in question, covering all of its variations." It is evident, however, that a formula should not cover variations due to impurities in the material analyzed, nor possible inaccuracies in analytical work. Both Clarke and Tschermak have their well-known theories concerning the composition of mica, and, seeing in the lithia-, iron-, and magnesia-varieties of tourmaline certain analogies, respectively, to muscovite, biotite and phlogopite, they both endeavor to force the tourmaline formulas to conform to their ideas concerning the constitution of mica. True, as shown by the analyses of Riggs,* there occur at Auburn, Rumford and Hebron, Maine, pseudomorphs of muscovite after tourmaline; but the fact need not necessarily be taken to indicate that tourmaline is closely related to mica, nor that, by what may be designated as a sort of *molecular cleavage*, tourmaline is transformed into mica. The author is familiar with these Maine localities, and he does not believe that such alterations are common, nor does he believe that it is common to find similar alterations at other localities where tourmaline is found. Muscovite is evidently a very stable molecular compound; it occurs more or less pure as pseudomorphs after many minerals, and not, as it would seem, because each and every one of these minerals contains as a nucleus the muscovite molecule, but because muscovite has such a tendency to form under a variety of conditions that it develops, provided materials suitable for its formation are at hand. Thus it is supposed that an ancient mud flat becomes converted to a shale and eventually to a mica schist, as the result of indurating and metamorphic processes,

* This Journal, III, xxxv. p. 41, 1888.

and yet mud and shale are not supposed to contain the chemical nucleus of muscovite; but, rather, they contain constituents suitable for the formation of muscovite.

It is quite common at the Maine localities to find cavities in quartz and other minerals once occupied by tourmaline crystals, and often there still remain in these cavities remnants of the fresh, unaltered tourmaline. The tourmaline fragments appear as if etched, and much material has evidently been dissolved and carried away. Hence replacement pseudomorphs of muscovite after tourmaline might well result from the subsequent filling of such cavities by muscovite. Replacement pseudomorphs are well illustrated by specimens from the Maine localities in the Brush Collection. The specimens referred to exhibit cavities containing remnants of fresh unaltered tourmaline, and as secondary minerals we now find cookeite and quartz deposited on the walls of these cavities, with absolutely nothing to indicate that the material for the formation of the cookeite and quartz was derived from tourmaline, for it could equally well have been derived from lepidolite and other minerals; in fact the tourmaline originally in a cavity could scarcely have furnished sufficient lithia for the formation of the cookeite, provided that not a trace of the lithia was carried away. The fact, therefore, that pseudomorphs of muscovite after tourmaline have been described, cannot be taken and accepted as proof that tourmaline is closely related to the micas, and that the formula of tourmaline must show close analogies to the formulas of the minerals of the mica group.

Clarke's formula for the tourmaline acid is $H_{20}B_2Si_6O_{31}$, which requires the ratio of $SiO_2$: $B_2O_3$: Total Hydrogen to be 6 : 1·5 : 29, or 4 : 1 : 19·33. It is true that three of the analyses of Riggs yield this ratio (Nos. 18 and 19, page 22, and also No. 20, if it is assumed, as is by no means proved,* that the titanium exists as $Ti_2O_3$). Assuming $Ti_2O_3$ as existing in No. 20, the ratio becomes 4·00 : 0·97 : 19·2.

These three analyses then, out of a total of twenty by Riggs, alone support Clarke's formula. Two of the three varieties (No. 19, black tourmaline from Pierrepont, N. Y., and No. 20, brown tourmaline from Gouverneur, N. Y.) have been analyzed by Rammelsberg, a fact ignored by Clarke. It may be claimed by some that Rammelsberg's analyses are not to be taken into consideration because they are old. It should be said, however, that Rammelsberg undoubtedly determined the bases and loss on ignition in his analyses with considerable accuracy, and his results need not be wholly ignored. Assuming that $SiO_2$ and $B_2O_3$ are present in tourmaline in the ratio 4 : 1, it becomes

* See suggestions by Foote and the author, p. 117 of their article, loc. cit.

possible to determine both $SiO_2$ and $B_2O_3$ by difference, and this treatment of Rammelsberg's analyses was fully discussed by Foote and the author. In the present instance it is only necessary to repeat here the ratios between $SiO_2$ and Total Hydrogen derived from the two analyses, which are to be compared with Numbers 19 and 20 (page 22) of Riggs.

| | $SiO_2$ : Total H. | $SiO_2$ : Total H. |
|---|---|---|
| Black tourmaline, Pierrepont, analyzed in 1889, | 4·00 : 20·2 | 3·96 : 20·00 |
| Brown tourmaline, Gouverneur, analyzed in 1850, | 4·00 : 20·7 | 3·86 : 20·00 |

Thus Rammelsberg's results for these two varieties conform to the $H_{20}B_2Si_4O_{21}$ formula, rather than to the more complicated one proposed by Clarke. The analysis of the black tourmaline from Pierrepont is one of the last, if not the very last, analysis made by Rammelsberg, and he claimed for it a high degree of accuracy.* The ratio derived from it is certainly very close to 4:20.

As an aluminium boro-silicic acid, Clarke writes his formula in linear form as follows:

$$Al_5(SiO_4)_6(BO_2)_3.BO_3H_3.H_{12}.$$

The composition of the black tourmaline from Pierrepont (I) and the brown tourmaline from Gouverneur (II), as derived from Riggs' analyses, are then expressed by him as follows:

$$\text{I.}\begin{cases} 13Al_5(SiO_4)_6(BO_3)_3.BO_3Ca.Mg_4H_4 \\ 7Al_5(SiO_4)_6(BO_3)_3.BO_3Mg.Mg_4H_4 \\ 2Al_5(SiO_4)_6(BO_3)_3.BO_3Na_3.Al_2Na_4H_2. \end{cases}$$

$$\text{II.}\begin{cases} 5Al_5(SiO_4)_6(BO_3)_3.BO_3Ca.Mg_4H_4 \\ 3Al_5(SiO_4)_6(BO_3)_3.BO_3Mg.Mg_4H_4 \\ 2Al_5(SiO_4)_6(BO_3)_3.BO_3NaH.Al_2Na_2H_4. \end{cases}$$

The above molecular mixtures when united become:

I. $Al_{114}Mg_{87}Ca_{13}Na_{19}H_{84}B_{68}Si_{132}O_{652}$ and
II. $Al_{64}Mg_{35}Ca_5Na_6H_{42}B_{30}Si_{60}O_{310}$.

Thus, taking multiples of a molecule containing a large number of atoms, and admitting of many variations in the replacement of the hydrogen atoms, it becomes a matter not of chemical, but rather of arithmetical skill to so choose the numbers that the calculated percentage values shall agree with the results of the analyses: and all this labor when there is good evidence for believing that owing either to slight defects in the analyses or impurities in the materials the two analyses in question fail by a little only to give ratios like those of the remaining analyses.

* Abhand. K. Akad., Berlin, 1890.

Another difficulty also, which Clarke evidently recognizes, is that there is no appropriate place in his molecule for the attachment of fluorine, and hence he suggests that the fluorine may sometimes replace the group $BO_3$, an equivalent, as stated by him, which is strongly indicated in the cappelenite group of minerals. Now from a chemical standpoint the group cited containing cappelenite, melanocerite, caryocerite and tritomite, seems poorly adapted for illustrating an important chemical principle, since the composition of all of the minerals of the group is very complicated, and only in the case of one mineral, tritomite, have direct determinations of $B_2O_3$ been made. Clarke's formula, it will be observed, is applicable directly to the three analyses of Riggs' (Nos. 18, 19 and 20, p. 22) which are low in bases, or high in silica: it will therefore be convenient to designate it as the *acid formula A*. In order to adapt his formula to the many analyses in which the ratio of $SiO_2$: Total Hydrogen is approximately 4: 20, Clarke presents a modification of his formula consisting in the substitution of a basic, bivalent, aluminium-hydroxide radical (AlOH) for two of the hydrogen atoms of his acid, and he always represents the (AlOH) radical as replacing the two hydrogen atoms attached to $BO_3$. Fluorine in this formula is considered as combined with aluminium to form a bivalent radical (AlF) isomorphous with (AlOH) instead of replacing the $BO_3$ group. A hypothetical molecule containing the (AlOH) radical and employed for expressing the composition of the green tourmaline from Haddam Neck is as follows:

$$Al_6(SiO_4)_6(BO_3)_3.BO_3(AlOH).Al_3Li_3H_4.$$

By substituting for the metals in the foregoing formula their equivalent of hydrogen, and simplifying, there results an expression which may be designated the *basic formula B*, so designated because it contains more hydrogen atoms than the *acid formula A*. The two are given together for comparison:

*A*, *Acid formula*, $H_{20}B_2Si_4O_{21}$.
*B*, *Basic formula*, $H_{21}B_3Si_6O_{22}$.

The empirical formula of the tourmaline acid, as derived by Foote and the author, $H_{20}B_2Si_4O_{21}$, is equivalent to $H_{20}B_3Si_6O_{21\frac{1}{2}}$, which is exactly midway between the *acid and basic formulas* of Clarke. Thus in order to find expressions that will yield calculated percentage values agreeing with the several analyses becomes again not a matter of chemical science, but rather an arithmetical problem, and one, too, which is bound to succeed; for, given the two formulas, some mixture of the molecules can be found to fit any analysis which falls within the limits

of Clarke's two types. Thus to express the composition of the green tourmaline from Haddam Neck, where the ratio of $SiO_2$: Total Hydrogen is very close to 4:20, Clarke employs an equal number of *basic* and *acid* molecules as follows:

*Basic.* $10Al_5(SiO_4)_6(BO_2)_2.BO_3(AlOH).Al_2Li_2H_4$.

*Acid.* $\begin{cases} 3Al_5(SiO_4)_6(BO_2)_2.BO_3Ca.Fe_4H_4 \\ 1Al_5(SiO_4)_6(BO_2)_2.BO_3Ca.Al_3NaH_2 \\ 6Al_5(SiO_4)_6(BO_2)_2.BO_3NaH.Al_3NaH_2. \end{cases}$

Prof. Clarke is very ingenious in his use of figures, and the agreement between the calculated percentages and the results of the analysis is indeed most satisfactory; but what is gained? The analysis gave a ratio of almost exactly 4:20 and a mixture of ten of the *basic* and ten of the *acid* types of Clarke's molecules must yield a ratio of exactly 4:20; hence it is a foregone conclusion that the theory must agree with the analysis. In order to bring about the agreement, however, a mixture of molecules is employed containing an aggregate of 1092 atoms.

If we are to accept the idea that formulas must in some way be found to suit all analyses, and, therefore, it is necessary to have pairs of formulas of acid and basic types, why not accept as the acid type for tourmaline the formula proposed by Rammelsberg, $H_{18}B_2Si_4O_{20}$? By substituting two bivalent (AlOH) groups for four hydrogen atoms, and then reducing to the simple hydrogen expression, we obtain for the basic type $H_{22}B_2Si_4O_{22}$, and by the proper replacement of the hydrogen atoms by metals and the combination of the two types of formulas, theoretical compositions could be calculated to a degree with all of the analyses. Indeed, these two formulas have some advantage over Clarke's, in that they are simpler, and priority, at least for one of them, can be claimed. Doubtless other pairs of formulas could be devised which would suit all variations presented by tourmaline analyses.

One other illustration presented by Clarke in support of his theory may here be cited, black tourmaline from Auburn, Maine, No. 2 of Riggs (page 22). The composition is expressed as follows:

*Basic.* $35Al_5(SiO_4)_6(BO_2)_2.BO_3(AlOH).Fe_4H_4$.

*Acid.* $\begin{cases} 2Al_5(SiO_4)_6(BO_2)_2.BO_3Ca.Fe_4H_4 \\ 27Al_5(SiO_4)_6(BO_2)_2.BO_3NaH.Al_3NaH_2. \end{cases}$

The aggregate number of atoms in the above mixture of molecules is 3499. Let it be observed (page 22) that as far as the ratio of $SiO_2$: Total Hydrogen is concerned this analysis is one of the very best, the ratio of $SiO_2$: Total Hydrogen being 4:20·03, which would require the basic and acid types of

Clarke's molecules to be present in nearly equal proportion. There are employed by Clarke, however, 35 *basic* and 29 *acid* molecules, from which the ratio of $SiO_2$: Total Hydrogen = 4:20·06 is readily calculated: thus the ratio as derived from Clarke's molecular mixtures is farther removed from 4:20 than that derived from the analysis itself, and yet Prof. Clarke makes the following statement: "It will be noticed that the molecule A" (with him the basic one) "is in excess of the other two; a condition which fits the analyses, but which is incompatible with the formula proposed by Penfield and Foote." It may be stated, however, that the $H_{20}B_2Si_4O_{21}$ formula of tourmaline is not based upon hypothetical molecular mixtures, but, fortunately, upon actual analyses, and good ones, like the one by Riggs last cited, where the ratio is almost exactly 4:20. This example furnishes a good illustration of the fact that ratios are more serviceable in support of a formula than comparison between percentage values.

And, finally, Prof. Clarke, in the concluding pages of this article, presents his reasons for believing that the radical ($=Al-BO_2$) may be replaced "in part by the similar groups ($=Al-OH$) and ($=Al-F$)," or, in other words, that hydroxyl and fluorine are equivalent to, and isomorphous with, $BO_2$. Clarke bases this conclusion upon the fact that, in many of the analyses of Riggs, and Jannasch and Kalb, the amount of $B_2O_3$ found is not sufficient to yield a ratio of $SiO_2:B_2O_3=4:1$ (see page 22), and the deficiency seems to him to be too great to be due to experimental errors. For explaining the occasional low determinations of $B_2O_3$ referred to, there is a far simpler way than the one proposed by Clarke: special pains were taken by Foote and the author to ascertain the conditions for accurately determining $B_2O_3$ in tourmaline, and it was found that by fusing the mineral with five times its weight of sodium carbonate and extracting with water, a little boron was still retained by the residue; a fusion of the residue with another portion of sodium carbonate was therefore made, and the boron was then determined by the well known Gooch method. It was further demonstrated that two fusions with sodium carbonate were sufficient for extracting all of the $B_2O_3$. Professor Riggs has kindly informed the author that in making his boron determinations by means of the Gooch method, he fused only once, but used, however, ten times as much sodium carbonate as mineral. It is hence probable that a double fusion with five times the weight of sodium carbonate is better than a single fusion with ten times the weight. As may be seen on page 22 the ratio of $SiO_2:B_2O_3$ is very close to 4:1 in the majority of Riggs' analyses. All who had occasion to determine boron prior to the description by Gooch of his admira-

ble method, unite in testifying that accurate and reliable estimations of $B_2O_3$ were exceedingly difficult, in fact almost impossible, to obtain. Jannasch and Kalb employed Bodewig's* modification of Marignac's method for estimating $B_2O_3$, weighing boron as $KBF_4$; hence, considering the complex character of tourmaline, their determinations are certainly as close to the truth as could be expected (see page 22), especially when it is taken into consideration that some boron would be lost if a double fusion with alkali carbonate was not made.

Tschermak seeks to explain the composition of tourmaline as a mixture of two complex silicate molecules, as follows:

$$Si_{12}B_6Al_{16}Na_4H_6O_{62} = B_6Al_4O_{18}.4(Si_2Al_2NaH_2O_{12}) = Tu.$$
$$Si_{12}B_6Al_{10}Mg_{12}H_6O_{62} = B_6Al_4O_{18}.2(Si_2Al_2H_2O_{12}.Si_2Mg_6O_{12}) = Tm.$$

The radical $(Si_2Al_2NaH_2O_{12})$, in *Tu* is the generally accepted paragonite formula, and $(Si_2Al_2H_2O_{12}.Si_2Mg_6O_{12})$ in *Tm* is Tschermak's typical meroxene formula, except that a part of the hydrogen in meroxene is replaced by potash. Thus tourmaline is supposed by Tschermak to contain mica molecules in combination with the boron radical $B_6Al_4O_{18}$.

In order to express the composition of the two varieties of tourmaline analyzed by Foote and the author, the following relations are employed: for Haddam Neck, $Tu_{443}$ $Tm_{71}$ and for DeKalb, $Tu_{132}$, $Tm_{37}$. The foregoing relations when written out in linear form are, respectively, $Si_{612}B_{308}Al_{774}Mg_{84}Na_{176}H_{394}O_{3213}$ and $Si_{600}B_{200}Al_{378}Mg_{444}Na_{52}H_{326}O_{2150}$. Thus with expressions, each containing about 5500 atoms, Tschermak shows that the calculated percentages agree in a satisfactory manner with the results of the analyses after the latter have been very much simplified by making numerous substitutions and recalculating to 100 per cent.

The two formulas of Tschermak, $Si_{12}B_6Al_{16}Na_4H_6O_{62}$ (*Tu*) and $Si_{12}B_6Al_{10}Mg_{12}H_6O_{62}$ (*Tm*) are both derived from an acid $H_{60}B_6Si_{12}O_{62}$, which is three times the empirical formula $H_{20}B_2Si_4O_{21}$ proposed by Foote and the author. Tschermak states that to refer tourmaline to the simpler acid $H_{20}B_2Si_4O_{21}$ is a decided step in the wrong direction, since it was shown ten years ago that the three-fold formula was correct. True, by taking suitable mixtures of Tschermak's *Tu* and *Tm* molecules, it is possible to calculate theoretical percentages which agree closely with the results of simplified analyses, but that fact does not necessarily prove the correctness of the formulas under consideration, and that the true constitution of tourmaline has been established. In his admirable *Lehrbuch der Mineralogie* Tschermak gives the composition of both pyrite

* Zeitschr. Kryst., viii, p. 211, 1883.

and marcasite as $FeS_2$; calcite and aragonite as $CaCO_3$; rutile, octahedrite and brookite as $TiO_2$; and cyanite, andalusite and sillimanite as $Al_2SiO_5$. If, therefore, for these compounds the simplest formulas are employed, it seems certainly a great presumption to state that in the case of tourmaline the complex three-fold formula had been definitely proved.

Finally Tschermak, who, like Clarke, does not seem to take into consideration that some analyses may not be reliable, tries to explain the composition of the tourmalines from Pierrepont and Gouverneur (Nos. 19 and 20, p. 22), and Tamatawe (No. 9, page 22), by assuming the existence of a third molecule, $Tn = Si_{12}B_6Al_8Mg_{12}H_8O_{61} = B_6Al_4O_{15} \cdot 2(Si_2Al_2H_4O_{11} \cdot Si_2Mg_6O_{12})$, in which the portion $(Si_2Al_2H_4O_{11} \cdot Si_2Mg_6O_{12})$, is supposed to be analogous to phlogopite. It does not seem reasonable, however, to believe that the tourmalines from the localities in question are essentially different from those from other localities, and need, consequently, different formulas, especially since we have a recent analysis of the Pierrepont, and an early analysis of the Gouverneur varieties of tourmaline by Rammelsberg, both of which conform to the $H_{20}B_2Si_4O_{21}$ formula.

*Summary.*—As shown by the tabulation of ratios on pages 21 and 22 there exist a series of recently made and carefully executed tourmaline analyses which give ratios of $SiO_2 : B_2O_3$: Total Hydrogen approximating closely to 4 : 1 : 20, from which the empirical formula of the tourmaline acid, $H_{20}B_2Si_4O_{21}$, is derived. That a few analyses do not yield ratios agreeing as closely as desired to 4 : 1 : 20 is not to be wondered at, when the difficulties presented by the analysis are taken into consideration, together with the fact that the material analyzed might not in all cases have been perfectly pure and homogeneous. As far then as analytical evidence may be relied upon for establishing the formula of a mineral, it may be considered *as definitely proved that the empirical formula of the tourmaline acid is* $H_{20}B_2Si_4O_{21}$. The science of inorganic chemistry has not yet reached such a state of development that it can be proved, as stated by Tschermak, that the threefold formula, $H_{60}B_6Si_{12}O_{63}$, is the correct one. The empirical formula $H_{20}B_2Si_4O_{21}$, proposed by Clarke, can rest only on the analytical evidence supplied by a few analyses of Riggs and one by Jannasch and Kalb which yield ratios approximating to 4 : 1 : 19·33 (page 22), and there are good reasons for believing that these ratios would not be obtained a second time if the analyses were repeated. Since tourmaline always yields sufficient water to form two hydroxyl radicals, it may be considered *as probably, if not absolutely, proved that the formula of the tourmaline acid should be* $H_{18}(OH)_2B_2Si_4O_{19}$. Beyond this point it seems safe only to speculate and it cannot be con-

sidered that the ideas presented are capable of being definitely proved. All of the analyses indicate that at least half of the hydrogen atoms of the tourmaline acid, are replaced by aluminium, and this fact, coupled with the idea that it seems reasonable to unite the two hydroxyl radicals with the two boron atoms, led to the suggestion by Foote and the author* that the characteristic feature of all varieties of tourmaline is an *aluminium-borosilicic acid*, $H_9Al_3(B.OH)_2Si_4O_{19}$. In this acid the mass effect of the $(Al_3(B.OH)_2Si_4O_{19})$ is regarded as so overwhelming that it makes no difference how the nine remaining acid hydrogen atoms are replaced, whether largely by aluminium and to a trifling extent by bivalent metals and alkalies, or largely by magnesium and to a trifling extent by aluminium and alkalies, the result in all cases is tourmaline with its characteristic crystalline structure. That trivalent, bivalent and univalent metals, playing as it were the role of isomorphous constituents, may unite in replacing the nine hydrogen atoms of the tourmaline acid, is indeed a remarkable feature of isomorphism, but it furnishes an explanation of the composition of tourmaline, and one which can be comprehended, in part at least.

Looked at from the standpoint of an instructor, what explanation of the chemical composition of tourmaline can be given to a student provided the ideas of Tschermak prevail? Only this, that the composition is exceedingly complicated; that there are two molecules *Tu* and *Tm* (page 30), exhibiting certain analogies to minerals of the mica group, which mix in varying proportions, and that by taking appropriate multiples of the two molecules theoretical compositions can be calculated to agree with the results of analyses, provided the latter are very much simplified. By taking molecular mixtures containing in the aggregate several hundred and even thousand atoms, as done by Clarke (page 28) and Tschermak (page 30), it would seem as though chemists or perhaps arithmeticians might aspire to devise formulas for expressing the chemical composition of any sort of substance of which any kind of an analysis has ever been made.

* Loc. cit., p. 118.

Sheffield Laboratory of Mineralogy and Petrography,
Yale University, New Haven, June, 1900.

ART. IV. — *Studies in the Cyperaceæ;* by THEO. HOLM. XIII. *Carex Willdenowii* and its allies. (With three figures in the text.)

TORREY, in his monograph of North American *Cyperaceæ*, was the first author to call attention to the peculiar habit of *Carex Willdenowii* Schk., which he suggested separating from *Carex* proper as a distinct genus, and to which the name "*Phyllostachys*" would be appropriate. The foliaceous bracts and the distinctly articulated base of the style were the characters, which Torrey considered as being of sufficient importance for the establishment of this new genus. Later authors have all agreed, however, in not adopting this genus, but merely to accept *Phyllostachys* as a section of *Carex*, and it seems very natural, since such articulation of the style is also observable in several other species of very remote relationship, besides that the foliaceous bracts are not characteristic of this species alone. A strange coincidence is, that another botanist made a similar suggestion, but many years later, concerning a *Carex*, which in many respects is analogous with *C. Willdenowii*. Duval-Jouve discovered in France, near Montpellier, a species of *Carex*, which he named *C. œdipostyla* on account of its articulated style-base, and in which he noticed the rhachis to be winged and the bracts to be foliaceous; this author suggested the establishment of a new section: "*Œdipostyla*," and he considered *C. moesta* Kunth and *C. phalaroides* Kunth as its nearest allies, since, also, these possess a "stylus basi bulboso-incrassatus." Moreover Duval-Jouve proposed *C. phyllostachys* Mey. as a member of this same section, on account of its small number of female flowers, its foliaceous bracts, its winged rhachis, the shape of its utricle and finally its articulated style-basis. But, on the other hand, Duval-Jouve does not seem to have known *C. Willdenowii* and he evidently did not know of Torrey's monograph, since he makes no allusion to this; he would, no doubt, have counted *C. Willdenowii* among his *Œdipostylæ* inasmuch as the utricle of this species differs less from that of his new species than that of *C. phalaroides* and *C. moesta*. We may thus consider *Phyllostachys* and *Œdipostyla* as analogous forms of our genus *Carex*, but it will be necessary to remove some of the species, which formerly have been considered as representatives of these sections.

In examining the section *Phyllostachys* as adopted by Carey,* this contains, as understood by him, only *C. Willdenowii* Schk., *C. Steudelii* Kth. and *C. Backii* Boott, all of

* For references consult the bibliography appended to this article.

which may surely be regarded as closely related to each other, thus forming an apparently natural section or group. The same view was, also, held by Tuckermann, who placed them as his *Phyllostachyæ* next his *Careyanæ*, in which we find *C. plantaginea*, *C. gynomane* and *C. depauperata*. It was Professor L. H. Bailey that first enlarged the section *Phyllostachys*, and this author includes not only the three species enumerated above, *C. Willdenowii*, etc., as a subsection "*Bracteatæ*" (*Bractoideæ* Bailey), but also *C. Geyeri* Boott and *C. multicaulis* Bail. as representing another subsection "*Phyllostachyæ*," however with no very clear distinction. As a matter of fact, the section *Phyllostachys* became confused by this enlargement, which is readily noticeable from the statement by Professor Bailey that the section is not only "to be regarded, probably, as an offshoot of the *Montanæ*, but also to be connected with the *Laxifloræ* by *C. multicaulis*, being related to *C. Hitchcockiana*." It is true that Drejer considered his *Carices dactylostachyæ* as derived from his *C. sphæridiophoræ*, but this author would not have included the true *Phyllostachys* in any of these, judging from the diagnosis, while he might have included *C. Geyeri* among the *Dactylostachyæ*. In a lately published paper on the *Carices* of South America, a German author, Rev. G. Kükenthal, follows Prof. Bailey's disposition of *Phyllostachys*, and includes another species, *C. Sellowiana* Schl., which, however, shows no marked affinity to either *C. Willdenowii* or to *C. Geyeri*. Rev. G. Kükenthal, moreover, considers *Phyllostachys* as a subsection of Drejer's *Sphæridiophoræ*, which does not seem to be in conformity with the original diagnosis of this section. While thus Torrey's *Phyllostachys*, even if reduced to a section, has been maintained through so many years, Duval-Jouve's *Œdipostyla* does not seem to have gained recognition at all. In the Catalogue of European species of *Carex*, Dr. H. Christ has only enumerated *C. œdipostyla* as one of the *Digitatæ* Fries and placed it between *C. Halleriana* Asso and *C. pilulifera* L., while this same author has counted *C. depauperata* Good and *C. olbiensis* Jord. among the *Phyllostachyæ* of Torrey. If we consider the *Digitatæ* as understood by Dr. Christ, these contain representatives that are so little related to each other, that we must combine the *Sphæridiophoræ*, the *Dactylostachyæ* and the *Lamprochlænæ* with each other in order to get them all together. It may be, however, that *C. œdipostyla* is in some respects related to, for instance, *C. digitata* L., as suggested by Dr. Christ, but we cannot find any characters by which we might connect this with *C. pilulifera* or with *C. supina* Wahlbg. Future research must decide the proper place for *C. œdipostyla;* in the present paper we intend only

to discuss the position of the old section *Phyllostachys*, as defined by Torrey.

We have seen from the above that the section has been considered as an offshoot of the *Montanæ* Fr., which would mean to indicate some relationship between the *Sphæridiophoræ* on the one side and *Phyllostachys* on the other. We have, also, seen that it has been regarded as a subsection of the *Sphæridiophoræ*, which would even indicate a still closer relationship to these. The question is now whether our conception of the *Sphæridiophoræ* allows any such combination, if we take this in absolute accordance with Drejer, the author, who established the section. As long as we quote these sections as those of Drejer, and not "ex parte," we are supposed to follow the diagnosis strictly with no modifications whatsoever.

Let us read what Drejer says about the *Sphæridiophoræ*, on page 9 in his Symbolæ Caricologicæ: "Spica mascula unica. Spicæ foemineæ una vel plures, rotundatæ, sibi et masculæ approximatæ, sessiles. Bracteæ membranaceæ nervo dorsali excurrente herbaceo, vel herbaceæ ad basin membranaceæ. Perigynium membranaceum, pube hirsutie vel tomento vestitum, caryopsin arcte includens, rostro breviore longioreve apice scarioso-hyalino subbilobo. Stigmata terna, caryopsis trigona. Centrum habet hic grex in *C. pilulifera, ericetorum* cet., ex quibus character sumendus est. Ortum ducit inter monostachyas, nominatim in *C. Wormskjoldiana Hornem*," etc. The central species are all of ordinary habit; none possess foliaceous bracts replacing the *squamæ;* in none of these are there androgynous spikes on long axillary, basal peduncles; in none of these is the rhachis winged or zigzagged, nor is the male portion of the inflorescence so inconspicuous as in *Phyllostachys;* furthermore the utricle is not extended into a long, straight and rough beak in any of these. It seems difficult to understand, how any author could see such close relationship to exist between these sections, so distinct do they really appear. And even if we, agreeing with Drejer, see no objection for admitting species with almost simple or very little decompound inflorescence among such, which possess a number of separate spikes, androgynous or with separate sexes, we nevertheless cannot detect any connecting forms by which we might unite the *Sphæridiophoræ* or *Dactylostachyæ* with *Phyllostachys*, inasmuch as we cannot even consider *C. Geyeri* and *C. multicaulis* as members of this section, the *Phyllostachys* of Torrey.

It is now interesting to notice, that Drejer did not only decline to accept *Phyllostachys* as a genus, but that he did not even consider any of its species with enough significance to constitute even a special section of *Carex*, although he was well acquainted with these, at least with *C. phyllostachys, C. Willde-*

*nowii* and *C. Steudelii*. However, since authors of recent years have seen no difficulty in retaining this as a section, it will be necessary to analyze it again in order to decide the actual importance of its morphological characters: the structure of the inflorescence.

*Carex Willdenowii* possesses a terminal, androgynous spike with male flowers at the top, and a few lateral similarly androgynous, which are developed on long peduncles from the axils of the basal leaves. The plant thus shows a somewhat peculiar habit, which is not frequently met with in the *Carices genuinæ*, but which, to some extent, suggests certain species of *Vigneastra* Tuckerm. If we consider the simple androgynous spike by itself, this is just one of the fundamental characters of the old group "*Monostachyæ*" with its sections *Psyllophoræ* and *Capitatæ;* but if we, furthermore, include the basal, long-peduncled spikes as being merely a part of the main inflorescence, the plant becomes better referable to the group *Heterostachyæ*. In these the lateral peduncles are provided with a clado-prophyllon at their base, an organ which is, also, present in *C. Willdenowii*. The basal position of these lateral spikes, or to be exact "spicate inflorescences," is very characteristic in *C. Willdenowii*, while these are situated higher up on the culm in most of the *Heterostachyæ*, and are more or less remote from each other, as we remember from *C. sylvatica* Huds., *C. laxiflora* Lam., etc. This distinction, drawn from the basal position of the lateral inflorescences in *C. Willdenowii* and its nearest allies *C. Steudelii* and *C. Backii*, is not, however, applicable only to these species, but to several others, which show no affinities or immediate relationship to the members of *Phyllostachys*. It is to be observed in *C. basilaris* Jord., *C. phalaroides* Kth., *C. pedunculata* Muhl., *C. Linkii* Schk. and in *C. œdipostyla* Duv.-Jouve, which may belong to the sections *Trachychlænæ* and *Dactylostachyæ* of Drejer. While thus our species of *Phyllostachys* may be arranged very naturally among the *Heterostachyæ*, still another disposition may be made when we examine the section *Vigneastra* of Tuckermann. As described by this author, these species possess decompound, ramified inflorescences, which are always androgynous, male at the top, and may have two or three stigmata. If we, carefully, compare these species with *Phyllostachys*, we soon discover that each branch of *C. cladostachya* Wahlbg., for instance, corresponds to a complete flower-bearing stem of *C. Backii* with its terminal and axillary inflorescences.

The clado-prophylla P in *C. cladostachya* (fig. I) correspond to those same organs, P, in *C. Backii* (fig. II); the bracts L correspond to the green leaves L in *C. Backii*, of which only the scars are indicated; the androgynous spikes A, B, C and D to those of

*C. Backii.* Finally the terminal androgynous spike A is equivalent with the same, A, in this species, and the utriculi, painted black in the figures, correspond to those of *C. Backii.* We might even go still farther and confine ourselves to the uppermost lateral branch in *C. Backii* (B in fig. II), which showed the

EXPLANATION OF FIGURES.

FIG. I. *Carex cladostachya* Wahlbg., lateral branch of inflorescence, enlarged. A = the terminal, B, C and D = the lateral spikes, all androgynous with the male flowers at the top; P = clado-prophyllon; L = leaves, the lowest one removed. Utriculus is painted black in all the spikes.

FIG. II. *Carex Backii* Boott, the complete inflorescence of a single shoot, enlarged. Letters as above; the leaves (L) have been removed. All the spikes are androgynous with the male flowers at the top; the uppermost lateral spike (B) is developed upon the rhacheola of an abnormal utriculus, of which the female flower is merely rudimentary. Utriculus is painted black.

FIG. III. *Carex œdipostyla* Duv.-Jouve; the terminal inflorescence, showing the zigzagged rhachis and the leaf-like bracts; copied from Duval-Jouve, but reduced one-half.

common case of a prolonged, flower-bearing rhacheola. In this specimen, the little branch B constitutes the rhacheola bearing four female, one-flowered spikelets and one terminal, male spike, while the utricle at the base has acquired a corresponding development as the clado-prophyllon P in *C. cladostachya*: thus the ramified rhacheola demonstrates exactly the same structure as the branches B, C and D in *C. cladostachya*. Considered from this point of view the section *Phyllostachys* Torr. is morphologically inseparable from any of the other sections of *Eucarex*, of *Vignea* or *Vigneastra*. Utriculus shows in these sections or subgenera, as they have been considered by some authors, the same plasticity of developing either as a membranaceous clado-prophyllon at the base of peduncles or as a normal utriculus, surrounding the female flower. The extension of the rhacheola may sometimes result in the suppression of the female flower, but not always. Both Duval-Jouve, Gay, Roeper and Schulz enumerate not a few cases where the female flower had developed normally; besides that the rhacheola protruded through the orifice of the same utriculus, bearing one or two female flowers with bracts, utricles and pistils. The clado-prophyllon at the base of the lateral peduncles has, also, been observed to contain a pistil, perfect or rudimentary. But a case like that which we have observed in *C. Backii* differs from most others by the development of a complete male spike besides the female ones at the base; it is evidently an exceptional occurrence, and it illustrates exactly one of the minor inflorescences in the genus *Schœnoxiphium*. As a matter of fact, this genus, as well as *Uncinia* and *Kobresia*, show a very striking resemblance to *Carex*, when considered from a morphological viewpoint.

As regards the development of the lower bracts in *Phyllostachys* into green leaves instead of membranaceous scales, this character does not seem to be of much importance as far as concerns the systematic position of the species. Similar green bracts are, also, known from the other sections, for instance in specimens of *Carex scirpoidea* Michx. of the *Sphæridiophoræ*, where a single or sometimes even several female spikelets may be seen subtended by leaf-like bracts, a case which we noticed in the mountains of Greenland. Moreover in *Carex Hilairei* Boott, the lower bracts of the androgynous spike are developed into long leaves, as figured by Boott (Plate 468); this species may probably be referred to the *Dactylostachyæ*. Furthermore *C. phyllostachys* Mey., *C. multicaulis* Bail. and *C. œdipostyla* Duv.-Jouve show similar leafy bracts, and have, therefore, been regarded as members of *Phyllostachys*, although they do not seem to possess the most important character of this section and are, perhaps, better placed in a section parallel

with the *Dactylostachyæ*. The zigzagged rhachis is another character, which has been claimed as important to *Phyllostachys* Torr., yet this is, also, noticeable in *C. arctata* Boott, in *C. phyllostachys* Mey. and *C. œdipostyla* Duv.-Jouve and several others. The winged margins of the rhachis is, on the other hand, a rare feature in *Carex*, and seems only to have been observed in the species of *Phyllostachys* Torr., in *C. œdipostyla* and *C. phyllostachys*. Finally to be mentioned is the utricle, which, as already stated by Drejer, is one of the most essential organs for classifying the *Carices* in sections, and he distinguishes between three categories within *Eucarex:* "Prima est, ubi margines tam arcte circa caryopsin concrescunt, ut verum rostrum non formetur; perigynium tum aut apice perforatum est, aut brevissime rostellatum ore integerrimo vel subemarginato. (*C. polytrichoides, baldensis, pallescens, atrata, vulgaris* cett.) Secunda est, ubi rostrum quidem formatur, sed ab inferiore perigynii parte non aut vix distinguitur, estque apice hyalinum, bilobum aut irregulariter bifidum. (*C. pilulifera, ericetorum* et aff., *frigida* et aff. cet.) Tertia denique et perfectissima est, ubi rostrum verum et distinctum, apice distincte bifidum aut bicuspidatum formatur. (*C. distans* et aff., *C. vesicaria* et aff. cet.) These sections are again divided into "greges": *Carices melananthæ*, etc., which are distinguished by the consistency of utriculus, whether membranaceous or spongy, glabrous or hairy, and furthermore by the disposition of the sexes, though of lesser importance.

If we now apply the classification, based upon the structure of utriculus, it is readily to be seen that *Phyllostachys* as it stands at present, including *Bracteatæ* and *Phyllostachyæ*, is no very natural section: that the *Bracteatæ* are quite distinct from the latter. We have already in the preceding given our views about the position of Professor Bailey's *Phyllostachyæ* as more properly to be arranged parallel with the *Dactylostachyæ*, while *Phyllostachys* proper shows certain analogies with Drejer's *Hymenochlænæ*. In any case the distinction that has hitherto been drawn between *Phyllostachys* and the other sections is by no means tenable, nor have any accordances been proved to exist between these species and Professor Bailey's *Phyllostachyæ: C. Geyeri*, etc. Moreover, when Drejer did not exclude the distribution of the sexes as being of some importance to the classification, he, nevertheless, was well aware of the fact that "*formæ hebetatæ*" do exist in most, if not in all, the "greges," which he proposed. These "*formæ hebetatæ*" constitute such species as may naturally be looked upon as old types of the respective sections or "*greges*," for instance *C. scirpoidea* Michx. as being the type of *Sphæridiophoræ*, etc. By combining the morphological

features of the extreme forms, the simpler with the higher developed, we cannot avoid noticing that they occasionally unite in some characters, which may be understood as exhibiting their descent through modifications from a common, or fundamental type. We may in this manner take *Phyllostachys* of Torrey to be a lesser developed form of *Hymenochlænæ*, and these species "sensu strictiori" do represent several analogies in habit and structure. But we have, also, demonstrated in the preceding, that *C. Buckii*, *C. Willdenowii* and *C. Steudelii* show characters that are, also, common to *Vigneastra*, which, however, does not necessarily indicate anything more than this section possesses characters that may be compared with those of the "*Carices genuinæ*." *Vigneastra*, as far as these peculiar species are understood, represent some certain transition between *Vignea* and *Eucareæ*. And if it were not for the structure of utriculus and the three stigmata in *C. Willdenowii*, we might have had just as good reason for placing this among the *Vigneæ* as a highly developed type, combining these with *Vigneastra* of Tuckermann. And in regard to the systematic position of *Vigneastra*, if this is to be retained as a subgenus, it may be most naturally placed between *Vignea* and *Eucareæ*, as suggested by Rev. G. Kükenthal, instead of as a section between *Microrhynchæ* and *Hymenochlænæ* as proposed by Professor Bailey. In returning to our *Phyllostachys*, the species by which it is represented in accordance with Torrey, may seem naturally to be referred to the *Hymenochlænæ*, but as extreme and poorly developed forms; they may occupy a position almost as far from the central types: *C. sylvatica* Huds. and *C. cherokeensis* Schw. as *C. nepalensis* Sprgl. and *C. longipes* Don:

*Hymenochlænæ.*

I. Spicis androgynis, apice masculis, paucifloris. (*C. Willdenowii*, *C. Steudelii* et *C. Backii*.)

II. Spicis simplicibus sexu distincto plus minus densifloris. (*C. sylvatica* Huds., *C. cherokeensis* Schw. cet.)

III. Spicis androgynis, apice masculis, plus minus densifloris. (*C. nepalensis* Sprgl., *C. longipes* Don).

In the preceding pages we have attempted to demonstrate the systematic position of these species, formerly constituting the genus *Phyllostachys* Torr.; we shall, now, briefly discuss the internal structure of these in order to demonstrate the differences between them and *C. Geyeri*, *C. œdipostyla* and *C. multicaulis*. On the other hand, we freely admit, that divergencies in anatomical structure may not necessarily indicate distant relationship, especially not if we adopt the classifi-

cation of Drejer, where the species are arranged not in accordance with such artificial characters as are applied for the separation of *mono-*, *homo-* and *heterostachyæ*, or of *di-* and *tri-stigmaticæ*, but in accordance with purely natural affinities. It becomes, thus, evident that each of Drejer's "*greges*" or sections, as we may call them, is really an aggregate of a number of apparently very diverse forms, beginning with the "*formæ hebetatæ*" and passing gradually over into "*formæ centrales*," from which again a number of allied species, but somewhat differently developed, extend towards the limits of the section as "*formæ desciscentes*." An anatomical investigation of some of these parallel forms, the "*hebetatæ*" for instance, will no doubt reveal certain analogies with the corresponding "*formæ hebetatæ*" of other sections, while the central types may be very distinct. In this way the anatomical characters become obscure, and it will be necessary to make many comparisons between the various forms of each section, before we shall know where to draw the distinction between the characters of the section "as its own," and those, which may be regarded as inherited from old types through its "*formæ hebetatæ*." Our anatomical study of *Carex Willdenowii* and its allies must, therefore, necessarily be incomplete, but may, perhaps, be useful in further research, at least as a contribution to comparative studies of other species of the genus. We shall not, however, confine ourselves to these species, but we will compare their structure with that of *C. œdipostyla*, *C. Geyeri* and *C. multicaulis*. The structure of utriculus is, no doubt, the most important, yet, as will be shown, some interesting characters may, also, be obtained from the root, the stem and the leaves. In regard to the localities, from where our material was gathered, we might state that both *C. Willdenowii* and *C. Steudelii* were collected in the woods near Brookland, D. C.; that the former especially prefers shaded places in rich woods, while the latter inhabits drier ground in thickets or open woods; *C. Backii* was received from Mr. James M. Macoun in Ottawa, as collected on dry, grassy and rocky places in open woods and thickets near Ottawa; *C. Geyeri* from the Rocky Mountains in Montana and British Columbia, in somewhat damp ground; *C. multicaulis* from Wyoming; *C. œdipostyla* from thickets near Montpellier in southern France.

### *The root.*

The epidermis and hypoderm show a uniform structure in all three species: *Carex Willdenowii*, *C. Steudelii* and *C. Backii*. The cortex is thin-walled throughout in the last species, but

shows a distinctly thickened outer zone in the two other species. The inner cortex shows the usual tangential collapsing. Endodermis is exceedingly thick-walled in *C. Willdenowii* and *C. Backii*, but not so in the third species. The pericambium is more or less thick-walled in all three species and it is, also, interrupted by all the proto-hadrome vessels. In *C. Backii* we noticed that the average number of pericambium-cells between each two proto-hadrome vessels was only two or three, while there were four in the others. The conjunctive tissue was quite thick-walled in *C. Steudelii* and *C. Willdenowii*, but much less so in *C. Backii*. The root-structure is thus very uniform in these species, and agrees very much with that of *C. œdipostyla*, except that the pericambium is much more thick-walled in this species, besides that there are here mostly five pericambium-cells between each two proto-hadrome vessels. Very different is the structure exhibited by *C. Geyeri* and *C. multicaulis*. The cortex in the former consists exclusively of very thick-walled parenchyma, which is more or less collapsed though without leaving any lacunes; in the other species, *C. multicaulis*, it is only the outermost five or six strata that are thick-walled, while the inner are quite thin-walled, but not collapsed, although the root was apparently of the same age as the others. The endodermis is exceedingly thickened, especially on the inner walls, and very porose. The pericambium, which is not very thick-walled, is in both species only interrupted by some of the proto-hadrome vessels, but in different ways: in *C. multicaulis* every other proto-hadrome vessel bordered on endodermis, in almost regular alternation, while in *C. Geyeri* there was only one vessel out of thirteen which did not border on the endodermis; in some other specimens we noticed that fourteen of twenty-three proto-hadrome vessels were situated inside the pericambium.

*The rhizome*

is cespitose and very short in our species with the exception of *C. Geyeri*, in which there is a creeping rhizome, but of very short internodes and sympodial as in most of the other *Carices*. The cortical parenchyma is quite broad and somewhat thickened all through in *C. Steudelii*, but not so in *C. Willdenowii*. The endodermis is thickened like an O—endodermis in both species. The stereome is only to be observed as accompanying the mestome-bundles, which it surrounds completely, while it does not occur in the cortex as independent strata or groups. The mestome-bundles are irregularly scattered in several, about four bands, and are nearly all perihadromatic; there is, furthermore, a solid, central pith of slightly thickened cells. In *C.*

*Geyeri* the cortical parenchyma shows about eight thick-walled strata near the periphery, while the inner ones are very thin-walled; otherwise the structure of the stereome, the endodermis, etc., is like that of *C. Willdenowii* and *C. Steudelii*.

*The stem.*

The above-ground stem is somewhat rough from prickle-like projections from the epidermis and triangular in *C. Willdenowii*, *C. Steudelii* and *C. Backii*. However, when we examine the structure closer, it is readily seen that the outline is so sharply triangular that the term "three-winged" may be well applicable to these species. The cuticle is smooth and thin in all three species; the epidermis shows a distinct thickening of the outer walls, with the exception of the cone-cells; stomata are quite abundant. The cortical parenchyma is very poorly developed in *C. Steudelii*, consisting only of one stratum short, roundish cells, which border on wide lacunes. In *C. Willdenowii* this same parenchyma is better developed and shows several layers with relatively narrow lacunes; in *C. Backii* there are distinct palisades, but the lacunes are very wide in this. The stereome is thickwalled in *C. Willdenowii* and *C. Backii*, but not so in the third species; it accompanies the mestome-bundles either as hypodermal groups or separated from the epidermis by the cortex; it is, also, present on the hadrome side of the mestome-bundles; it reaches its highest development in the three wings, where it, furthermore, occurs as isolated groups, not being in contact with any mestome-bundles. These, the mestome-bundles, are very regularly arranged in one band near the periphery and represent larger oval in alternation with smaller, almost orbicular bundles, when viewed in transverse sections; the parenchyma-sheath is thinwalled, and the mestome-sheath shows its inner cell-walls to be distinctly thickened. A thinwalled pith occupies the center of the stem; it is hollow in *C. Backii*, solid in the other species.

In *C. œdipostyla* the stem is triangular, but without being winged, and the outer cell-walls of epidermis are more heavily thickened than in the former species; the cortex is more open, there being very distinct intercellular spaces besides lacunes of quite considerable width. The stereome is thickwalled, but does not occur separate from the mestome-bundles, which are here represented in two concentric bands, instead of but one as in the former species; the mestome-sheath shows the cells to be thickened all around. A partly hollow pith occupies the center of the stem. In *C. Geyeri* and *C. multicaulis* the stem is longer than in the former species and shows, also, a

much more solid structure; the cortex constitutes a compact palisade-tissue with relatively small lacunes, especially in the latter species. The stereome occurs in larger groups and is very thickwalled, but invariably accompanying the mestome-bundles; the sharp angles of the pentagonal stem of *C. Geyeri* have no isolated stereome, but merely cortical parenchyma; the terete stem of the other species possesses a larger number of mestome-bundles and, consequently, it contains, also, more stereome. The mestome-bundles constitute a single band and the mestome-sheath is very heavily thickened. The solid pith is thickwalled in *C. Geyeri*, but thinwalled in the other.

*The leaf*

is narrow, but flat in *C. Willdenowii* and *C. Steudelii*, relatively broad in *C. Backii*. The cuticle is thin and smooth in the former species, but quite thick in the latter. Epidermis exhibits several modifications; it is perfectly glabrous and smooth on the upper face in *C. Steudelii* and *C. Willdenowii*, and is differentiated into a row of bulliform cells just above the midrib; above the stereome the epidermis, viewed "en face" consists of narrower and shorter cells than those which cover the mesophyll. If we examine the lower surface of the leaf we notice a corresponding structure, but there are no bulliform cells, and stomata are observable outside the mesophyll; these are but slightly projecting and possess a wide but shallow air-chamber. If we consider the leaf of these species in cross-sections, we notice that the outer wall of epidermis is slightly thickened and somewhat projecting in the shape of very minute papillæ on either side of the midrib, but only on the lower surface. In *Carex Backii* the epidermis-cells are very short outside the stereome, much shorter than we observed in the former two species; their outer wall is very thick and we find here small wart-like projections from the epidermis, which form several rows on each side of the bulliform-cells, besides that there are four such projections around each stoma. The mesophyll is differentiated into a distinct palisade-tissue on the upper face of the leaf of *C. Steudelii* and *C. Willdenowii*, while it consists of roundish cells with large intercellular spaces on the lower face, almost as a typical pneumatic tissue; large lacunes traverse the mesophyll in both species. In *C. Backii*, on the other hand, the mesophyll is nearly homogeneous throughout the blade, very open and without palisade-cells. The stereome is thickwalled in *C. Willdenowii* and *C. Steudelii*, but quite thinwalled in *C. Backii*. It accompanies the mestome-bundles as hypodermal groups on either face, at least in the larger bundles, and there is, also, an iso-

lated group in each of the two margins. The mestome-bundles are arranged in one plane, larger alternating with smaller ones; the parenchyma-sheath is thin-walled and colorless; the mestome-sheath shows distinctly thickened inner cell-walls. The bracts, which subtend the one-flowered, female spiculæ in *C. Steudelii*, *C. Backii* and *C. Willdenowii* are leaf-like, at least the lower ones, and show a structure corresponding to that of the proper leaves, only that they are relatively narrower and possess more stereome than these. The bracts of the uppermost female spikelets are, on the contrary, scale-like, awned, membranaceous and with hyaline margins like the scales of the *Hymenochlænæ* in general.

In comparing the leaf of *C. Steudelii*, *C. Backii* and *C. Willdenowii* with that of *C. œdipostyla* we notice almost the same structure; but the outer wall of epidermis is thicker in this species, and without any development of papillæ, as we noticed in *C. Backii* for instance; the mesophyll is very open and is not differentiated into any distinct palisade-tissue. The stereome is quite thick-walled, and the mestome-sheath has its inner cell-walls considerably more thickened than we observed in the former species. The leaves of *C. Geyeri* and *C. multicaulis* are longer and much narrower than in any of the former species; they are slightly conduplicate with a distinct keel in the former, but in the latter the midrib is not projecting. The outer cell-wall of epidermis is quite thick, especially so in the bulliform cells, which are here relatively small and occur as a single group above the midrib, when viewed in transverse sections. No papillæ are visible around the stomata, but in *C. multicaulis* there are a few rows of such projections on each side of the bulliform cells, similar to those observed in *C. Backii*. The stomata are level with epidermis and confined to the lower surface of the blade. The mesophyll is a dense palisade-tissue with a lacune between each two mestome-bundles in *C. Geyeri*, but is more open in the other species. The stereome is extremely thick-walled in both species and accompanies the mestome-bundles, besides that it, also, occurs as isolated groups in each of the two margins in *C. multicaulis*, but not in *C. Geyeri*. The mestome-bundles themselves show the same structure as we have found in the other species, described above, but the mestome-sheath is more thick-walled than in these.

*Utriculus.*

This little organ furnishes the most essential characters in distinguishing the sections and even the species of *Carex*. It is almost bottle-shaped in *C. Steudelii* with a long, straight and rough beak, and is readily distinguished from that of *C. Willde-*

*nowii*, where the beak is shorter and less pronounced. However the internal structure is the same for these two species. The outer wall of epidermis on the dorsal face is somewhat thickened, on the ventral face it is much less so; there is but little mesophyll displayed in a few strata and no stereome, not even by the two mestome-bundles, in which, furthermore, the mestome-sheath is quite thin-walled. In *C. Backii* the utricle shows a similar structure with the exception of a few stereome-cells on the leptome-side of the two mestome-bundles. A much firmer structure is exhibited by *C. œdipostyla* in which the epidermis is quite thick-walled on either face, besides that the mesophyll is more compact and occurs in several layers; moreover we find in this species very thick-walled stereome, not only on either face of the mestome-bundles, but also as several isolated groups between these. There are more than two mestome-bundles and these possess a very thick-walled mestome-sheath. The utricle of *C. Geyeri* and *C. multicaulis* has a very short beak like *C. œdipostyla;* it is perfectly glabrous and smooth. The epidermis is heavily thickened on both faces; the mesophyll is poorly developed, and the stereome, which is quite thick-walled, is in *C. Geyeri* confined to the mestome-bundles, while in the other species it occurs as several isolated groups between them.

It would seem from the above as if *C. Steudelii*, *C. Willdenowii* and *C. Backii* are closely related to each other, but not to *C. œdipostyla*, *C. Geyeri* or *C. multicaulis*, hence the section *Phyllostachys*, as defined by recent authors, does not constitute a natural section. If we, moreover, consider those species, which by Torrey were the fundamental ones for his genus, it appears as if they are not sufficiently characteristic among themselves to necessitate the establishment of even a section. And the same is the case with *C. œdipostyla*. In regard to *C. Geyeri* and *C. multicaulis*, these do not possess very pronounced characters either, but similarly to the others may be arranged in some of the larger sections as "formæ hebetatæ." The species of Torrey's *Phyllostachys* appear, on the other hand, as inseparable from the *Hymenochlænæ*, of which they probably represent one of the earlier types. The earliest is unknown in this section, but was perhaps monostachyous; but we might, also, suppose that the *Hymenochlænæ* developed parallel with one of the other sections from one common "forma hebetata," which then branched out into two or more distinct sections.

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*Bibliography.*

Bailey, L. H. : A preliminary synopsis of North American Carices (Proceed. American Acad. Sci., 1886.)

Bailey, L. H. : Studies of the types of various species of the genus Carex (Memoirs Torrey Bot. Club, vol. i, 1889).

Boott, Francis : Illustrations of the genus Carex, vol. i. London, 1858.

Carey, John : Carex in Gray's manual, 1st edition, 1848.

Christ, H. : Nouveau catalogue des Carex d'Europe (Bull. Soc. bot. Belgique, vol. xxiv, 1885).

Christ, H. : Appendice au nouveau catalogue des Carex d'Europe (Bull. Soc. bot. Belgique, vol. xxvii, 1888).

Clarke, C. B. : On *Hemicarex* Benth. and its Allies (Jonrn. Linn. Soc., vol. xx, London, 1884).

Drejer, S. : Revisio critica Caricum borealium (Naturhist Tidsskr., vol. iii, Kjœbenhavn, 1841).

Drejer, S. : Symbolæ Caricologicæ. Kjœbenhavn, 1844.

Duval-Jouve, J. : Sur un Carex nouveau (*Carex œdipostyla* J. Duv.-J.) (Bull. soc. botanique de France, vol. xvii, 1870).

Duval-Jouve, J. : Sur la présence d'un rachéole dans l'utricule du *Carex œdipostyla* J. Duv.-J. (Bull. Soc. botanique de France, vol. xxi, 1874).

Gay, I. : De caricibus quibusdam (Ann. d. sc. Botanique, Ser. 2, vol. x, Paris, 1838).

Klinge, Johannes : Vergleichend histiologische Untersuchung der Gramineen- und Cyperaceen- Wurzeln. Dorpat, 1879.

Kunth, C. S. : Enumeratio plantarum, vol. ii. Stuttgart, 1837.

Kükenthal, Georg : Die Carex vegetation des aussertropischen Südamerika (ausgenommen Paraguay und Südbrasilien) (Engler's Jahrb., vol. xxvii, 1899).

Lemcke, Alfred : Beiträge zur Kenntniss der Gattung Carex Mich. (Inaug. Diss. Königsberg in Pr. 1892).

Mazel, Antoine : Etudes d'anatomie comparée sur les organes de végétation dans le genre Carex (Thesis Genève, 1891).

Roeper, Johannes : Zur Flora Mecklenburgs. Pars 2. Rostock, 1844.

Schulz, August : Zur Morphologie der Cariceæ (Berichte d. Deutsch. bot. Ges., vol. v, 1887).

Tuckermann : Enumeratio methodica Caricum quarundam, 1843.

Torrey, John : Monograph of North American Cyperaceæ (Ann. of the Lyceum. New York, vol. iii, 1828–36).

ART. V. — *The Titration of Mercury by Sodium Thiosulphate;* by JOHN T. NORTON, JR.

[Contributions from the Kent Chemical Laboratory of Yale University—XCV.]

ACCORDING to J. J. Scherer* mercurous nitrate, mercuric nitrate and mercuric chloride may be estimated by direct titration with sodium thiosulphate, $Hg_2S$, $2HgS.Hg(NO_3)_2$, and $2HgS.HgCl_2$ being the precipitates obtained in each case. I have been unable to obtain access to Scherer's original publication, but Sutton† gives the following very general directions for this process:

(*a*) "*Mercurous salts.*—The solution containing the metal as a protosalt only is diluted, gently heated and the thiosulphate delivered in from the burette at intervals, meanwhile well shaking until the last drop produces no brown color. The sulphide settles freely and allows the end of the reaction to be easily seen. One cm³ of the $\frac{1}{20}$ normal solution of thiosulphate = 0·02 grams Hg or 0·0208 HgO.

(*b*) *Mercuric nitrate.*—The solution is considerably diluted, put into a stoppered flask, nitric acid added and the thiosulphate cautiously added from the burette, vigorously shaken meanwhile, until the last drop produces no further precipitate. Scherer recommends that when the greater part of the metal is precipitated the mixture should be diluted to a definite volume, the precipitate allowed to settle and a measured quantity of the clear liquid taken for titration; the analysis may then be checked by a second titration of the clear liquid if needful. One cm³ of $\frac{1}{20}$ normal thiosulphate = ·015 of Hg. or ·0162 of HgO.

(*c*) *Mercuric chloride.*—With mercuric chloride the end of the process is not so easily seen. The very dilute solution is acidified with hydrochloric acid, heated nearly to boiling, and the thiosulphate cautiously added so long as a white precipitate is seen to form; any great excess of the precipitant produces a dirty-looking color. Filtration is necessary to distinguish the exact ending of the reaction. One cm³ of $\frac{1}{20}$th normal thiosulphate = ·015 Hg or ·0162 HgO."

Fresenius‡ gives practically the same directions, but omits all mention of that portion of the process dealing with mercurous nitrate.

In view, therefore, of the scant information available on the subject and of the apparent difficulty of working the process accurately according to the directions given, an attempt was

* His Lehrbuch der Chemie, i, 513.
† Volumetric Analysis, p. 220.
‡ Quantitative Analysis.

made to ascertain whether the careful regulation of temperature, dilution and amount of acid present might not produce beneficial results.

That portion of the process dealing with mercuric chloride was first taken up. The mercuric chloride used was pulverized, dried at 100° and its purity proved by several determinations as mercuric sulphide. The sodium thiosulphate was made up of approximately $\frac{1}{20}$th normal strength and standardized on decinormal iodine, which in turn was titrated against decinormal arsenious acid made from pure resublimed arsenious oxide.

For the action of sodium thiosulphate upon the mercuric chloride Scherer gives the equation,

$$3HgCl_2 + 2Na_2S_2O_3 + 3H_2O = 2HgS.HgCl_2 + 2Na_2SO_4 + 4HCl.$$

According to my experience, the action results in the formation of a dense white precipitate which refuses to settle either by shaking or standing, thus making it impossible to fix the end reaction by reading the first drop of thiosulphate which produces no further white precipitate in the solution containing the mercuric chloride. Recourse must be had therefore to filtering. By far the quickest and neatest method is to use the asbestos filter deposited on a large perforated platinum cone.* This cone is set in a glass funnel by means of a rubber connector and the funnel is passed through the stopper of a large side-necked Erlenmeyer connected with an exhaust pump. A little asbestos fiber shaken in the liquid to be filtered was found to be very beneficial in preventing the precipitate from running through the filter. In all the following experiments the thiosulphate was run into the solution containing the mercuric chloride in excess, the whole shaken up with asbestos fiber, filtered and the excess of thiosulphate determined by $\frac{1}{20}$th normal iodine. This method of procedure seems to be far preferable to attempting to catch the end of the reaction by running in the thiosulphate until the last drop produces no precipitate. In the experiments shown in Table I no attention was paid to the temperature of the solution and the thiosulphate was run in until the liquid turned brown. In every case the solution was allowed to stand until there was no further visible change of color.

A glance at the table shows that the results are most irregular. In Table II is seen the result of regulating the temperature and the length of standing after the addition of the sodium thiosulphate.

* Amer. Chem. Jour., i, 321.

TABLE I.

| | $HgCl_2$ taken calc'd as Hg. grams. | $Na_2S_2O_3$ in excess. $cm^3$. | Volume at beginning. $cm^3$. | $HgCl_2$ found calc'd as Hg. grams. | Error. grams. |
|---|---|---|---|---|---|
| 1. | 0·0446 | 46·28 | 200 | 0·0343 | 0·0103— |
| 2. | 0·0354 | 46·28 | 400 | 0·0326 | 0·0028— |
| 3. | 0·0356 | 44·97 | 400 | 0·0225 | 0·0131— |
| 4. | 0·0345 | 44·5 | 100 | 0·0308 | 0·0037— |
| 5. | 0·0354 | 44·43 | 50 | 0·0326 | 0·0028— |
| 6. | 0·0382 | 22·59 | 50 | 0·0354 | 0·0028— |
| 7. | 0·0375 | 8·58 | 50 | 0·0385 | 0·0010+ |
| 8. | 0·0371 | 1·84 | 50 | 0·0304 | 0·0067— |
| 9. | 0·0731 | 2·28 | 50 | 0·0774 | 0·0043+ |
| 10. | 0·1486 | 9·34 | 50 | 0·1489 | 0·0003+ |

TABLE II.

| | $HgCl_2$ taken as Hg. grams. | Volume at beginning. $cm^3$. | Temperature. C. | Standing minutes. | $Na_2S_2O_3$ in excess. $cm^3$. | $HgCl_2$ as Hg. found. | Error. grams. |
|---|---|---|---|---|---|---|---|
| 1. | 0·0738 | 50 | 36° | 40 | 16·68 | 0·0494 | 0·0244— |
| 2. | 0·0741 | 50 | 70 | 15 | 15·42 | 0·0738 | 0·0003— |
| 3. | 0·0741 | 75 | 70 | 12 | 16·07 | 0·0733 | 0·0008— |
| 4. | 0·0744 | 50 | 70 | 10 | 14·6 | 0·0755 | 0·0011+ |
| 5. | 0·0764 | 50 | 72 | 7 | 6·77 | 0·0771 | 0·0007+ |
| 6. | 0·0762 | 50 | 75 | 10 | 8·54 | 0·0799 | 0·0037+ |
| 7. | 0·0756 | 50 | 73 | 15 | 9·99 | 0·0815 | 0·0059+ |
| 8. | 0·0774 | 50 | 68 | 15 | 10·84 | 0·0767 | 0·0007— |
| 9. | 0·0745 | 75 | 69 | 7 | 6·62 | 0·0805 | 0·0060+ |
| 10. | 0·0736 | 50 | 68 | 5 | 15·82 | 0·0714 | 0·0022— |

These results, although better than those of Table I, are still very uncertain. On the supposition that the change from white to black, which takes place in the solution after the addition of an excess of sodium thiosulphate more or less quickly according to the temperature, was due to an increased amount of HgS in the compound $2HgS.HgCl_2$, the next step was to ascertain whether this could be avoided by stopping the addition of the thiosulphate at the first indication of a change of color in the white precipitate, diluting the solution with a large amount of cold water and immediately throwing it on the filter. The following table (III) shows the result of the experiments.

In the case of quantities of mercuric chloride up to 0·1 gram the results shown in Table III are very satisfactory, but when larger amounts of mercuric chloride are used the errors again become prominent. In Table IV, the effect of lowering the temperature to 60° C. and of increasing the dilution to $100^{cm^3}$ is shown.

TABLE III.

| | $HgCl_2$ taken as Hg. grams. | Volume at beginning. $cm^3$. | Temperature. C. | $Na_2S_2O_3$ in excess. $cm^3$. | $HgCl_2$ found as Hg. grams. | Error. grams. |
|---|---|---|---|---|---|---|
| 1. | 0·0749 | 50 | 70° | 4·15 | 0·0751 | 0·0002+ |
| 2. | 0·0749 | 50 | 75 | 0·72 | 0·0728 | 0·0021— |
| 3. | 0·0756 | 50 | 72 | 1·46 | 0·0759 | 0·0003+ |
| 4. | 0·0753 | 50 | 70 | 2·57 | 0·0750 | 0·0003— |
| 5. | 0·0390 | 50 | 70 | 3·43 | 0·0395 | 0·0005+ |
| 6. | 0·0388 | 50 | 72 | 8·19 | 0·0390 | 0·0002+ |
| 7. | 0·0380 | 50 | 76 | 2·03 | 0·0393 | 0·0013+ |
| 8. | 0·1494 | 50 | 78 | 4·99 | 0·1498 | 0·0004+ |
| 9. | 0·1489 | 150 | 78 | 4·38 | 0·1512 | 0·0023+ |
| 10. | 0·1480 | 50 | 70 | 0·52 | 0·1438 | 0·0042— |
| 11. | 0·1498 | 50 | 78 | 1·47 | 0·1540 | 0·0042+ |
| 12. | 0·1484 | 50 | 71 | 2·09 | 0·1517 | 0·0033+ |
| 13. | 0·1480 | 75 | 72 | 1·59 | 0·1509 | 0·0029+ |

TABLE IV.

| | $HgCl_2$ taken as Hg. grams. | Volume at beginning. $cm^3$. | Temperature. C. | $Na_2S_2O_3$ in excess. | $HgCl_2$ found as Hg. grams. | Error. grams. |
|---|---|---|---|---|---|---|
| 1. | 0·0759 | 100 | 60° | 3·06 | 0·0766 | 0·0007+ |
| 2. | 0·0384 | " | " | 2·81 | 0·0387 | 0·0003+ |
| 3. | 0·1498 | " | " | 1·1 | 0·1500 | 0·0008+ |
| 4. | 0·1503 | " | " | 1·63 | 0·1506 | 0·0003+ |
| 5. | 0·1479 | " | " | 2·41 | 0·1480 | 0·0001+ |
| 6. | 0·1489 | " | " | 2·12 | 0·1503 | 0·0014+ |
| 7. | 0 2244 | " | " | 2·63 | 0·2259 | 0·0015+ |
| 8. | 0·1490 | " | " | 2·33 | 0·1484 | 0·0006— |
| 9. | 0·0758 | " | " | 2· | 0·0762 | 0·0004+ |
| 10. | 0·0383 | " | " | 2·58 | 0·0379 | 0·0004— |

From this table it is plain that Scherer's process for the estimation of mercury in the form of mercuric chloride is capable of yielding accurate results if carried out under certain fixed conditions. These conditions, which must be closely adhered to, are as follows: The solution containing the mercury in the form of mercuric chloride is placed in a liter flask, diluted to 100$^{cm^3}$ and heated to a temperature of 60° C. The sodium thiosulphate in $\frac{1}{20}$th normal solution is run in from a burette until the white precipitate formed begins to take on a brownish tinge. The solution is then diluted with cold water, some asbestos fiber added to coagulate the precipitate and the whole is quickly thrown on the filter. After careful washing of the precipitate, the filtrate is diluted to a definite volume, 3 grams of potassium iodide added and the excess thiosulphate

titrated with iodine and starch solution. The duration of the process need not exceed 15 minutes. It is worthy of note that there is no necessity of using any hydrochloric acid in addition to that formed in the reaction. This certainly eliminates one probable source of error—the interaction of hydrochloric acid and sodium thiosulphate.

In dealing with the estimation of mercury in the form of mercurous nitrate the same method of procedure was employed as in the case of mercuric chloride. A solution of mercurous nitrate was prepared by dissolving as much as possible of 20 grams of the salt in about 200$^{cm^3}$ of water, filtering off the clear liquid and diluting to a definite volume. The standard of the solution was determined by precipitation as metallic mercury by means of the electric current. Contrary to the statement made in Sutton, the brown precipitate of $Hg_2S$— formed as shown in the equation,

$$Hg_2(NO_3)_2 + Na_2S_2O_3 = Hg_2S + Na_2SO_4 + N_2O_4—$$

does not settle and leave a clear supernatant liquid, but the solution remains cloudy and it is impossible to see any end reaction. Although the conditions of dilution, temperature and amount of acid present were carefully considered, no arrangement or adjustment of these conditions was found under which satisfactory results could be obtained. Table V gives the result of experiments.

TABLE V.

| | $Hg_2(NO_3)_2$ taken as Hg. grams. | $HNO_3$ 1 : 3. $cm^3$. | Volume at beginning. $cm^3$. | Temperature. C. | $Na_2S_2O_3$ in excess. $cm^3$. | $Hg_2(NO_3)_2$ found as Hg. grams. | Error. grams. |
|---|---|---|---|---|---|---|---|
| 1. | 0·0148 | none | 50 | 50° | 4·28 | 0·0129 | 0·0019— |
| 2. | 0·0148 | " | 75 | 60 | 4·45 | 0·0117 | 0·0031— |
| 3. | 0·2976 | " | 300 | 60 | 12·67 | 0·2760 | 0·0216— |
| 4. | 0·1488 | " | 100 | 40 | 2·19 | 0·1386 | 0·0102— |
| 5. | 0·1488 | " | 100 | 50 | 6·92 | 0·1378 | 0·0110— |
| 6. | 0·1488 | " | 200 | 50 | 0·78 | 0·1388 | 0·0100— |
| 7. | 0·0744 | " | 100 | 65 | 0·73 | 0·0636 | 0·0108— |
| 8. | 0·0744 | 1 | 100 | 55 | 0·49 | 0·0733 | 0·0011— |
| 9. | 0·0744 | 2 | 100 | 40 | 1·16 | 0·0660 | 0·0084— |
| 10. | 0·0744 | 1 | 100 | 55 | 1·35 | 0·0685 | 0·0059— |
| 11. | 0·0744 | 1 | 100 | 55 | 0·82 | 0·0686 | 0·0058— |
| 12. | 0·0744 | ½ | 200 | 55 | 1·71 | 0·0685 | 0·0059— |
| 13. | 0·0744 | 4 | 100 | 40 | 1·77 | 0·0649 | 0·0095— |
| 14. | 0·0744 | 5½ | 100 | 40 | 1·34 | 0·0645 | 0·0099— |
| 15. | 0·0744 | 1 | 100 | 45 | 1·71 | 0·0654 | 0·0090— |
| 16. | 0·0744 | 10 | 100 | 45 | 1·55 | 0·0669 | 0·0075— |
| 17. | 0·1488 | 1 | 100 | 40 | 0·73 | 0·1391 | 0·0097— |

The errors in experiments 1, 3, 4, 5, 6, 10, 11, 12 and 17 are, proportionally to the amount of material handled, practically the same and this fact caused me to make a careful revision of all standards; but no mistake could be found. The reaction upon which the process depends requires the formation of $Hg_2S$, but this mercurous sulphide breaks down immediately into mercuric sulphide and mercury. The latter is probably acted upon by the free nitric acid present to form mercuric nitrate, which in turn is transformed into the compound $2HgS.Hg(NO_3)_2$ by the action of the thiosulphate. At any rate, with an error so large, whatever its source may be, the process is plainly impracticable.

The third step in Scherer's process deals with the action of sodium thiosulphate on mercuric nitrate. In the following experiments a solution of mercuric nitrate was prepared either by dissolving as far as possible 20 grams of mercuric nitrate in about $200^{cm^3}$ of cold water, filtering off the supernatant liquid and diluting to a definite volume (exps. 1–8), or by dissolving the salt in strong nitric acid and diluting (exps. 9–19). The standard of the solution was obtained by precipitation as metallic mercury by means of the electric current. The yellow precipitate, formed according to Scherer's reaction,

$$3Hg(NO_3)_2 + 2Na_2S_2O_3 = 2HgS.Hg(NO_3)_2 + 2Na_2SO_4 + 2N_2O_3,$$

on adding the sodium thiosulphate settles much better than in the case of either mercuric chloride or mercurous nitrate; but, as the supernatant liquid takes on a permanent yellow color towards the end of the reaction, it is impossible to see when the thiosulphate produces no further precipitation. On this account, therefore, the same method of procedure was adopted as in the case of the mercuric chloride and mercurous nitrate, i. e., filtration and titration of the excess of sodium thiosulphate with iodine and starch solution. The result of the experiments is shown in the following table.

These results seem to show the impossibility of obtaining accurate results according to Scherer's method for the determination of mercuric nitrate by direct titration with sodium thiosulphate. The constant plus error cannot be accounted for on the hypothesis that the nitric acid present decomposes the sodium thiosulphate, for in that case the error would lie in the other direction. It is more probable that the constitution of the compound $2HgS, Hg(NO_3)_2$ is not definite enough to make it the basis for an analytical process.

TABLE VI.

| | $Hg(NO_3)_2$ taken as Hg. grams. | Volume at beginning. $cm^3$. | $HNO_3$ 1 : 3 $cm^3$. | Temperature. C. | $Na_2S_2O_3$ in excess. $cm^3$. | $Hg(NO_3)_2$ found as Hg. grams. | Error. grams. |
|---|---|---|---|---|---|---|---|
| 1. | 0·1167 | 200 | none | 60° | 0·46 | 0·1384 | 0·0217 + |
| 2. | 0·1167 | 100 | 1 | 60 | 3·63 | 0·1348 | 0·0181 + |
| 3. | 0·1167 | 100 | 2 | 60 | 0·23 | 0·1375 | 0·0208 + |
| 4. | 0·1167 | 100 | none | 60 | 0·17 | 0·1360 | 0·0193 + |
| 5. | 0·1167 | 300 | " | 21 | 0·12 | 0·1232 | 0·0065 + |
| 6. | 0·1167 | 300 | " | 21 | 0·15 | 0·1375 | 0·0208 + |
| 7. | 0·1167 | 200 | " | 21 | 11·8 | 0·1461 | 0·0294 + |
| 8. | 0·1167 | 200 | 20 | 21 | 15·97 | 0·1403 | 0·0236 + |
| 9. | 0·1278 | 200 | none | 21 | 5·23 | 0·1647 | 0·0369 + |
| 10. | 0·1278 | 200 | " | " | 1·35 | 0·1653 | 0·0375 + |
| 11. | 0·1278 | 100 | " | " | 1·43 | 0·1662 | 0·0384 + |
| 12. | 0·0752 | 200 | " | " | 2·09 | 0·0996 | 0·0244 + |
| 13. | 0·0255 | 100 | " | " | 2·01 | 0·0280 | 0·0025 + |
| 14. | 0·0255 | 200 | 5 | " | 3·44 | 0·0264 | 0·0009 + |
| 15. | 0·0255 | 200 | 10 | " | 0·85 | 0·0334 | 0·0079 + |
| 16. | 0·0255 | 300 | none | " | 1·96 | 0·0264 | 0·0009 + |
| 17. | 0·0255 | 200 | " | " | 1·9 | 0·0287 | 0·0032 + |
| 18. | 0·0255 | 200 | " | " | 1·76 | 0·0290 | 0·0035 + |
| 19. | 0·0639 | 200 | " | 60 | 1·53 | 0·0831 | 0·0192 + |

In conclusion I wish to thank Prof. F. A. Gooch for his kind advice and assistance.

ART. VI.—*Selenium Interference Rings;* by A. C. LONGDEN.

SOME months ago, while at work on thin films deposited by cathode discharge, at the request of Mr. C. C. Trowbridge of Columbia University, I attempted to deposit for him a thin conducting film of selenium. The attempt was not successful; because, although the selenium was in the conducting form in the cathode, the film was always in the amorphous form, which is not an electrical conductor. A number of films were deposited under all sorts of conditions, but they were invariably amorphous and therefore non-conducting.

During the deposition of selenium, although no conducting films were produced, a very interesting and beautiful phenomenon was observed. The selenium cathode was small in comparison with the size of the glass plates upon which the films were deposited, and therefore the distribution of selenium was not uniform, the film being considerably thicker in the center than at the edges. The deposited material is sufficiently transparent to transmit large quantities of light through thicknesses of several wave-lengths; so that when light falls upon a film of varying thickness, the beams reflected from the upper and lower surfaces present interference phenomena similar to Newton's rings. The interference bands which were at first produced were so irregular that they could hardly be called rings, because of the lack of uniformity in the upper surfaces of the films; but after arranging the cathode in the form of a small globule, films increasing uniformly in thickness toward the center were obtained.

These films, when viewed by reflected light, present concentric systems of circular interference fringes of great beauty and remarkable brilliancy. The transparent selenium film is deposited upon plane glass, and, having a convex upper surface, it constitutes a very thin plano-convex lens. The interfering beams of light, however, are not reflected from the surfaces of an air film, between the convex lens and a second plane, but from the two surfaces of the selenium lens itself. As this lens is thickest in the center, instead of being thinnest in the center as in Newton's air film, the selenium rings increase instead of decrease in width and brilliancy, counting from the center outward. For the same reason the order of the colors is red, yellow, green, blue, violet; instead of violet, blue, green, yellow, red; and, instead of having a black center when viewed by reflected light, as is the case with Newton's rings, the color of the center depends upon the order of the ring, counting from the margin inward.

It will be seen by considering the geometrical conditions which govern radiation from a point to a plane, that if our cathode is a small enough globule, the radius of curvature of the film will depend upon the distance of the cathode from the glass plane upon which the film is deposited. Accordingly, this distance determines the diameter of the rings, and the width of any particular ring. By placing the cathode at a suitable distance from the glass, it is very easy to obtain exceedingly brilliant rings as much as 8 or 10 millimeters in width and 4 or 5 centimeters in diameter.

These rings are so brilliant that they are as easily projected upon the screen as ordinary lantern slides; and without the usual precautions in regard to size and illumination demanded in projecting Newton's rings with a glass lens and plate. They should, however, be projected by reflected light.

I am not aware that Newton's rings of this character, namely, interference rings from the reflecting surfaces of a very thin plano-convex lens, have heretofore been produced by any process whatsoever. The physical conditions connected with selenium rings are of a simpler character than those which exist in the case of ordinary Newton's rings, and they may, therefore, afford physicists new opportunities for the study of this subject.

Physical Laboratory of Columbia University,
April 20, 1900.

ART. VII.—*Carboniferous Bowlders from India;* by B. K. EMERSON.

IN the spring of 1894, I was in the office of the Geological Survey of India and Dr. Fritz Nötling unpacked for me and explained a fine series of the bowlders of the Carboniferous Glacial period of the Salt range in northwestern India.

They had been obtained partly from the talus and partly from the conglomerate itself, and he was kind enough to give me samples of the different forms. Later, Dr. King, the Director of the Survey, observing the unconscious but silent admiration with which I examined the finest bowlder of the series, packed it up and sent it after me to my lodgings. This is the largest bowlder in the figure and is 10 inches long.

It is a dark red rock halfway between a granite and a quartz porphyry and is perfectly scratched on four sides and rough and battered on the ends.

It is in color, shape, and kind and perfection of striation, so like the great bowlder, about 9 feet long, of red sandstone which stands in front of the Geological Museum at Amherst and which was taken from one of the streets at Amherst during the lowering of the latter, that I may cite a figure of the latter for comparison from my monograph of old Hampshire Co., Mon. xxix, U. S. G. S., pl. xxxiii, p. 192.

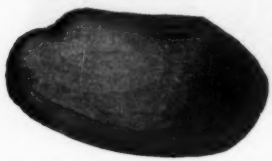
The bowlder with the cord around it was broken in dislodging it from the ledge and shows remains of the conglomerate cemented onto its upper surface. The bowlder on the small box is scratched on several small facets separated by sharp crests and has also fragments of the conglomerate attached.

The bowlder in front was not quite in focus but a dim line runs across the middle of the front from the upper left hand corner to the lower right hand corner and the portion below that line is distinctly striated, while the part above that line is weathered several millimeters deep by long exposure to the weather as it projected on the cliff while the lower portion was protected within the solid mass of the rock. Dr. Nötling explained to me the conditions of the occurrence and there can be no doubt about the glacial character and the Carboniferous age of the deposit. I send this short article because doubt has been expressed in a recent standard text-book as to the reality of the Carboniferous Glacial period.

## Art. VIII.—*A new Bivalve from the Connecticut River Trias;* by B. K. Emerson.

A few days ago my former assistant, Mr. Chas. S. Merrick, of Wilbraham sent me a large slab of sandstone of a buff color, much stained by malachite, containing several indistinct casts of a unio-like bivalve.

The shell seems to be one of those fresh or brackish water forms common in the Trias allied to the Unionidæ. It may be compared with the *Anoplophora lettica* Quenstedt,* and may be called *Anoplophora Wilbrahamensis.* It is a distinctly unio-shaped shell 38$^{mm}$ long, 18$^{mm}$ high, 7$^{mm}$ thick. The exterior is smooth with fine lines of growth. The mantel impression is quite deep as preserved on the central portion of the length. The beak rises very slightly and the hinge line is long and straight and there is in the figure what seems to be the impression of a long, posterior tooth, and above this a slight groove at the place of attachment of the ligament.



The large slab contains 14 imperfect casts, all of which may well belong to one species.

I do not know of any other bivalve shell from the Trias in Massachusetts.

* Pal., plate lxiii, fig. 28.

## Art. IX.—*The Statement of Rock Analyses;* by Henry S. Washington.

Of late years the importance of chemical analyses in the study of igneous rocks is generally recognized, and their publication and use is becoming more and more common.

Apart from improvements in methods and facilities, as well as increase in the number of workers, the main factor in this increase in the number of analyses published is the growing appreciation of their vital importance for a thorough comprehension of the rocks of the globe.

This importance of rock analyses to-day lies in their disclosing the bearing of the chemical composition of the rock masses on the deeper theoretical problems of petrology. Many of these, such as the differentiation of magmas, the genetic relationships of various rock bodies or parts of a complex to each other, or the true character and meaning of the so-called "petrographic provinces," are only to be solved by means of thoroughly good and trustworthy analyses.

There is an increasing tendency among some petrographers to regard the magma as one of the main objects of study, of which the solid rocks are simply the consolidated and accessible portions, many of their characters being to a great extent fortuitous and dependent on extraneous conditions of solidification and the like.

The chemical composition of the magma either persists as such in the rocks formed from it (as in Brögger's aschistic dikes), or is to be inferred if the magma has undergone changes such as those induced by differentiation (as in Brögger's diaschistic dikes), absorption of country rock or other causes. This chemical composition is, as far as we can tell at present, the single original character of the magma which is open to study after it has undergone the physical and physico-chemical changes which result in the formation of igneous rocks, whether aschistic or diaschistic.

Hence for obtaining a knowledge of these vast and highly important portions of the earth's crust, of their original characters, the conditions under which they exist and the changes which they may undergo, rock analyses are absolutely essential. It is true that physics also comes to our aid in certain directions, but this does not lessen the importance of the chemical investigation.

The practical use of analyses involves their collation or comparison one with another, either those of the rocks of one given region, or those of different regions with each other, or

of rocks belonging to any given group or kind. Scattered as they are through the literature, it is often a matter of some practical difficulty, or at least inconvenience, to bring several together under the eye so as to observe readily the features which it is desired to see. This inconvenience is increased by the fact that there is no uniformly adopted sequence in which the various constituents are stated.

In some cases, as in the publications of the U. S. Geological Survey, the analytical order is followed. The constituents are put roughly in the order in which they are determined in the course of the analysis.

Again a roughly chemical order is followed, either by putting all the acid radicals at the top of the column and the basic radicals below, as is usually done in Tschermak's Mittheilungen, or by putting $SiO_2$ first, followed by $TiO_2$, then the metallic oxides in the order $R_2O_3$, RO, $R_2O$, with $H_2O$, $P_2O_5$, Cl, etc. last of all, as is the custom of Roth, Zirkel, Rosenbusch, and many others, including the writer. But even here there are variations in the order followed, as in some cases CaO is put before MgO, and $K_2O$ before $Na_2O$.

A third method is that adopted of late years by Pirsson. This, which may be called the petrographic order, consists in putting the nine most important oxides first, beginning with $SiO_2$ and ending with $H_2O$, while the subordinate and more rarely occurring constituents follow after in the same general order.

A last method shows a lack of any system, the constituents being put down almost at haphazard, and with little apparent attempt at order or natural association. This method is fortunately rarely met with, and is to be dismissed at once as quite unworthy of consideration.

In consequence of this confusion not only is the inconvenience of and time required for copying and comparing analyses greatly increased, but there is introduced a positive danger of error due to unavoidable slips, which, unless the results are carefully and laboriously checked, is apt to lead to wrong conclusions.

The benefits then of a uniform system are evident, and it is probable that every petrographer has realized this to a greater or less extent. After some experience in the copying and use of rock analyses and full consideration of the subject, as well as discussion of the matter with other petrographers, I would propose that the third method mentioned above, which was, I think, inaugurated by Prof. Pirsson, be generally adopted, this presenting the greatest advantages to the petrographer, with a minimum of disadvantage.

A rock analysis, it must be remembered, is primarily intended for, and almost exclusively used by, petrographers. Therefore for him an arrangement on analytical or strictly chemical lines is neither advantageous nor appropriate. What he needs especially is an arrangement which shall bring the essential chemical features—both the percentage figures and the molecular ratios—prominently and compactly before the eye, so that the general chemical character and the relations of the various constituents may be seen at a glance. It is also of importance that the arrangement be such as to facilitate comparison of one analysis with another.

To the petrographer the eight oxides, $SiO_2$, $Al_2O_3$, $Fe_2O_3$, FeO, MgO, CaO, $Na_2O$, and $K_2O$, which in practically every case are present in preponderating amount, are, and must always remain, of prime importance. They are the oxides which, by their relative amounts, determine the chemical character of the rock. $H_2O$ and $CO_2$, which are also found sometimes in notable quantity, are chiefly of value as a measure of the freshness of the rock. The other constituents, while of great interest, are present in minute quantities and in general, especially as compared with the main oxides, influence the character of the rock only to a very limited extent, either entering into the composition of accessory and subordinate minerals, or replacing to a very small extent the more important oxides in the essential minerals.

Hillebrand's plea* for their determination is well founded, and it is of course a desideratum that all analyses should be complete as to the rarer constituents. This, however, is not always possible, and it will probably remain true as it is at present, that many otherwise good and serviceable analyses are incomplete in this respect, or only show determinations of a few of the rarer constituents, notably $TiO_2$, MnO, $P_2O_5$, and Cl.

By putting the eight main oxides together, then, the petrographer is able to see at a glance the character of the rock under study, and the molecular ratios of these oxides, which are the only ones of practical importance, may be written after them and so easily compared *inter se*. Furthermore, whether an analysis is complete or incomplete, these oxides, which are determined in every case, are always in the same relative position, so that the eye finds them without trouble, thus immensely facilitating comparison and study.

The question naturally arises as to the advisability of stating the analytical results, not in oxides, but in terms of the elements, oxygen being given as a separate constituent. This is

* Hillebrand, Bull. 148, U. S. G. S., p. 15, 1897.

done by some petrographers in the reduction of analyses for certain lines of work, though in these cases oxygen is omitted. This last seems to me a somewhat unjustifiable procedure, in view of the fact that oxygen makes up by far the greatest percentage in all the known terrestrial rocks.

It is true that we do not yet know whether the oxides exist as such in the magma or not, though the theories of physical chemistry seem to favor the view that they do. But apart from such considerations, the possible benefits to be obtained are so doubtful and meager that it seems scarcely justifiable at present to make any such sweeping change. Experience has shown the convenience and practicability of the present method for the study of rocks, and as it is sanctioned by long and universal usage, it had better be retained, and the results stated in oxides.

The statement of the analysis then will be divided into two divisions, the main portion, in which are placed the principal oxides, and the subordinate in which occur all the rest.

The order in which the constituents may be put is the next consideration. That which is here proposed is as follows:

$SiO_2$, $Al_2O_3$, $Fe_2O_3$, FeO, MgO, CaO, $Na_2O$, $K_2O$, $H_2O$ (ignit.), $H_2O$ (110°), $CO_2$, $TiO_2$, $ZrO_2$, $P_2O_5$, $SO_3$, Cl, F, S ($FeS_2$), $Cr_2O_3$, NiO, CoO, MnO, BaO, SrO, $Li_2O$.

As regards the main portion the sequence usually adopted seems eminently proper. This is $SiO_2$, $Al_2O_3$, $Fe_2O_3$, FeO, MgO, CaO, $Na_2O$ and $K_2O$. In this we start out with the chief acid radical and the constituent present in largest amount, and go through successively lower orders of oxides to the most positive radicals, the alkalis. At the same time they are presented in a way which brings the oxides together in their natural petrographic and mineralogic relations. The sesquioxides are together; ferrous iron follows ferric, MgO is next to FeO, as the two go hand in hand in the ferro-magnesian minerals; CaO is intermediate as is proper, since it is a constituent both of these and of the feldspars, and it is next to $Na_2O$, as it is associated with it in plagioclase.

$H_2O$ should follow $K_2O$, as it is a highly important and regularly determined constituent. I follow Hillebrand* in urging the separation of ignition and hygroscopic water, putting the former first, as being an essential ingredient. Next to these should come $CO_2$, as this, with $H_2O$, is a measure of the freshness of the specimen, and this character can, therefore, be told at a glance. Together also they constitute the "loss on ignition" so often given, and in this case can be connected by a bracket.

* Hillebrand, Bull. 148, U. S. G. S., p. 29, 1897.

After these it seems well to put the acid radicals which have been determined, following the main principle of the other division; $TiO_2$ and $ZrO_2$ should come first, then $P_2O_5$ and $V_2O_5$. $SO_3$ is put next instead of at the head of the lesser acid radicals, as it, like Cl which follows, is a constituent of the sodalite group. F comes after Cl, and then S or $FeS_2$ may be put.

Then come the subordinate metallic oxides, in the order $R_2O_3$, RO, $R_2O$. These would include $Cr_2O_3$, $(Ce_2O_3)$, NiO, (CoO), MnO, (CuO), BaO, SrO, $Li_2O$. Finally in rare cases C or N may be put at the last.

While the above order of arrangement is undoubtedly open to criticism in certain respects, yet it seems to the writer, as well as to other petrographers to whom it has been submitted, to be on the whole the most logical and convenient. It may be added that practical experience of it in the collection of a large number of analyses sustains this view.

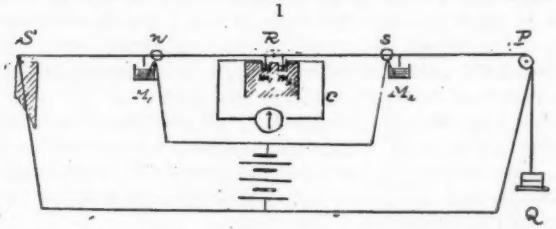
I would also urge the advisability of printing the important molecular ratios with each new analysis, wherever this is possible. The reader will be saved the trouble of calculating them for himself, and will thus immediately have a fuller comprehension of the character of the rock.

In this connection I would suggest, as a practical and convenient method for using analyses, the use of a card catalogue, the cards being printed with the oxides in their proper order. Experience has shown the utility of such a plan, and the time given to its preparation will be more than compensated for by that saved in reference and collation.

ART. X.—*A String Alternator;* by K. HONDA and S. SHIMIZU.

THE transverse vibration of a stretched iron wire was first used by M. Wien* as an interrupter for an induction coil. The vibration was produced by the mutual attraction between a magnet and the wire. Pupin,† however, replaced the driving force by the motion of a wire carrying an electric current in the magnetic field. A similar arrangement was also used by L. Arons.‡

Pupin's interrupter may be modified to serve as an alternator in the following way. As shown in the annexed figure, a




copper wire is horizontally stretched; one of the ends is fixed to a stout support S, and the other, passing over a small metallic pulley P, is attached to a weight Q. The wire is electrically insulated at the middle point R, so that no current can flow through the point but through the circuit C. Close to the middle point and just under it, two mercury cups $m_1$ and $m_2$ are placed; two short vertical wires fixed to the horizontal one are dipped into each of them. Again, at quarter distances from S and P, two short wires about $2^{cm}$ long are vertically fixed to the main wire; two cups $M_1$ and $M_2$ are placed under them for mercury contact. One pole of an accumulator is connected to these cups, and the other to S and P; $n$ and $s$ are two poles of a strong magnet (or better an electromagnet) horizontally placed close to the wire; the magnet maintains the wire in constant vibration. Evidently, there is a definite relation between the direction of the current and the poles of the magnet for continuing the vibration. This direction of the current is easily found by trials. A tap given to the wire so as to produce vibrations with a single node at the middle point sets the wire in constant vibration. By this arrangement, the mercury contact is made in turn at $M_1$ and $M_2$, so that the current passing through the portion of the circuit C changes

* M. Wien, Wied. Ann., xliv, 683, 1891.
† M. I. Pupin, this Journal, III, xlv, 325, 1893.
‡ L. Arons, Wied. Ann., lxvi, 1177, 1898; lxvii, 682, 1899.

its direction once in a complete vibration. Thus, suitably changing the length (by sliding two wedge-shaped blocks) or the tension (by changing the suspended weight) of the string, an alternating current of desired frequency is obtained.

Now, in the above method, only a part of the current employed can be turned to the alternating current; in case where a strong alternating current is required, it is sufficient to use two equal sets of accumulators; two poles of the one set being connected to $M_1$ and P, and those of the other to $M_2$ and S, so that the currents through the portion of the circuit C are directed in opposite sense. A sensitive galvanometer, inserted in the circuit, shows whether the mean strength of the alternating current in both directions is equal or not. The small difference in the current-strength can easily be effaced by adjusting the spark gap of the mercury contact.

To cut off the electrical connection at the middle point of the wire, the following method proved to be the most satisfactory. A silk-covered wire of suitable length is cut into two parts. The ends are twisted together like a rope for the length of 1$^{cm}$ and bent at right angles to the wire as shown in the annexed cut. The twisted portion of the wire is firmly bound together by a silk thread, and the remaining portion of the cover is scraped off. Though different specimens of wire were tried, copper and aluminum wires gave the most satisfactory result.

The simplicity of the present arrangement for obtaining an alternating current of definite frequency is one of its chief merits. The actual frequency, if the tension of the string be not small, was found not to differ by more than 1 per cent from the value calculated by the formula

$$n = \frac{1}{l}\sqrt{\frac{T}{\rho}},$$

where $l$ is the length, T the tension and $\rho$ the linear density of the wire. It was not difficult to obtain vibrations ranging from 30 to 1000 per second.

It may not be out of place to remark that in using the present arrangement, the self-induction of the circuit is to be reduced as small as possible, inasmuch as it diminishes the strength of the current. Hence in case the self-induction of the circuit be not small, a large number of accumulators must be used; otherwise the string would not maintain its vibrations. Measuring the mean strength of the current by an ampere-balance, we found but a small fluctuation, if the current does not exceed 1·5 amperes.

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## Art. XI.—*The Action of Light on Magnetism;* by Joseph Hall Hart.

The electro-magnetic theory of light assumes the existence of electro-magnetic waves of the required frequency in the ether and of their identity with ordinary light-waves. In consequence of the alternate electric displacements there should be an alternating magnetic field and we might expect the demagnetization of iron by light as a result, if the intensity of the light were gradually diminished. We have, however, little trustworthy evidence of the action of light on magnetism. The contradictory results obtained and the smallness of the effect have prevented the attainment of experimental results sufficient for definite conclusions on the subject. In particular, the action of light on the magnetism of iron bars presents a field in which, if ordinary care is taken, positive results should be obtained.

Several experimenters in the early part of the present century tried to magnetize iron and steel by the action of light. Morichini,* Christie† and Mrs. Somerville‡ obtained positive results from a series of experiments, while P. Riess and L. Moser,§ and John W. Draper‖ obtained negative results from precisely similar experiments, and the thing has been generally regarded as impossible. Under ordinary circumstances there can be little doubt that this is the case, but, according to Bidwell,¶ in a paper before the Physical Society in 1889, if a certain initial condition is fulfilled, we can find evidence of the action of radiation upon the magnetism of iron, and the fulfillment or non-fulfillment of this condition explains the diverse results of previous experimenters.

The condition is that the susceptibility of the bar AB to be operated upon shall be greater (or less) for a magnetic force in the direction AB than for an equal one in the direction BA. Iron bars having this property were obtained by the following method: A piece of soft iron rod, which may conveniently be 10 or 12$^{cm}$ long and from 0·5 to 1$^{cm}$ in diameter, is raised to a bright yellow heat and slowly cooled. When cold, it is placed inside a solenoid, through which is passed a battery current of sufficient strength to produce a field of about 350 or 400 C. G. S. units. The iron when removed from the coil is found to be permanently magnetized, and its north pole is marked

* See Christie. † Phil. Trans., 1826, p. 219.
‡ Phil. Trans., 1826, p. 132.
§ Annales de Chemie, xlii, 304.
‖ Journ. of Franklin Institute, Feb. 1835.
¶ Proc. Phys. Soc., London, April, 1889, p. 455.

for the sake of distinction with red sealing-wax varnish. The bar is then supported horizontally and in an east-and-west direction behind a small reflecting magnetometer, and over it is slipped a coil, which is shunted with a rheostat, the resistance of which can be gradually increased from 0 to 26 ohms. The coil can be connected by a key with a single battery cell, which is so arranged as to produce a demagnetizing force inside the coil. The resistance of the rheostat is slowly raised, so that more and more current passes through the coil, the battery key being alternately lifted and depressed until the magnetometer indicates that the iron bar as a whole is perfectly demagnetized. The strength of the demagnetizing force required varies according to circumstances: it is generally about one thirtieth or one twenty-fifth of the original magnetizing force.

A piece of iron thus treated possesses certain remarkable properties. The magnetization induced by a force acting in such a direction as to make the marked end a north pole, is greater than that caused by an equal force in an opposite direction. If such a bar be held horizontally east and west and tapped with a mallet, the marked end at once becomes a north pole. Application of heat or instantaneous application of flame causes a similar effect. If subjected to the action of a series of equal, alternating feeble magnetic forces, the marked end generally becomes a north pole, even if the last of the alternating forces may have tended to induce the opposite polarity. These were well-known effects, but in addition, Bidwell found that such a rod was remarkably sensitive to the action of light. When placed behind the magnetometer and illuminated by an oxy-hydrogen lamp about $70^{cm}$ distant, there occurred an immediate deflection of from 10 to 200 scale divisions, the magnitude of the effect varying in different specimens of iron. The magnetometer mirror was one meter distant from the scale and each division$=0{\cdot}64^{mm}$. In these experiments, as the action of the light was continued, the deflection slowly increased. When the light was shut off, the magnetometer instantly went back over a range equal to that of the first sudden deflection, then continued to move slowly in the backward direction toward zero. With a thick rod the slow movement was barely perceptible. He believed the first quick movement to be due to the direct action of radiation, and the subsequent slow movement to the gradually rising temperature of the bar. In several cases, the magnetism was of the opposite kind, and sometimes became north when certain portions of the rod were illuminated and south when the light acted upon other portions. This was probably due to irregular annealing and a consequent local reversal of the

direction of maximum susceptibility: it indicated, probably that the light effect was local, and confined to the illuminated surface. The effect varied directly as the intensity of the illumination; it was strongest for red light and independent of direction of vibration of incident light; and blackening the bar made the action much slower.

I first repeated and verified Bidwell's experiments. I procured eight pieces of the softest iron obtainable, of the following dimensions: each was $20^{cm}$ long; four were cylindrical rods, with diameters $13^{mm}$, $9{\cdot}5^{mm}$, $6{\cdot}5^{mm}$, $3{\cdot}5^{mm}$ respectively: they were designated rods A, B, C and D; four were of rectangular cross-section, $12\times3{\cdot}5^{mm}$, $12\times2{\cdot}5^{mm}$, $12\times1{\cdot}5^{mm}$, $12\times0{\cdot}75^{mm}$ respectively: they were designated, rods E, F, G and H. They were treated in the same manner as in Bidwell's experiments; they were carefully annealed, being heated in iron filings almost to the point of fusion and then cooled in ashes for about 25 hours. They were first strongly magnetized and then carefully and totally demagnetized. As a result of numerous trials and careful manipulation, I was able to get distinct effects from a gas jet at a distance of 6 inches. The following is a characteristic set of experiments: the light was perpendicular to the axis of the bar and only $3^{cm}$ of the north end of each rod was exposed. The deflection represents increase of magnetism as shown with magnetometer.

| Rod. | Area exposed to light. | Cross-section of rod. | Deflection. |
|---|---|---|---|
| A | $6{\cdot}15^{sq\ cm}$ | $1{\cdot}33^{sq\ cm}$ | 22·5 |
| B | 4·48 | 0·71 | 15·0 |
| C | 3·06 | 0·33 | 7·1 |
| D | 1·65 | 0·10 | 1·5 |
| E | 3·60 | 0·42 | 10·0 |
| F | 3·60 | 0.30 | 7·5 |
| G | 3·60 | 0·18 | 4·5 |
| H | 3·60 | 0·09 | 1·5 |

The effect was proportional to the area exposed, but not directly. It depended also on the intensity of the illumination. The action of the light does not appear to be here confined to the illuminated surface, as the effect is approximately the same, no matter which $3^{cm}$ of length of the bar is illuminated, and hence distance of illuminated surface from magnetometer has little or no effect. This is contrary to Bidwell's results and is probably due to the very regular annealing. The heating effect was also present. Light of long wave-length had greater effect. I did not attempt Bidwell's experiments in regards to polarized light and its action on the magnetism of the iron, since no positive results were obtained by him.

I then extended these experiments of Bidwell in an attempt to learn more in regard to the nature of this action of light on magnetism. Every cause of molecular disturbance favors the magnetization of a bar subjected to a magnetizing force, and also favors its demagnetization after it has been withdrawn from the field. Vibration has a specially marked effect upon iron. Ewing* has shown that if a bar of this metal be kept from the slightest vibration one can obtain residual magnetizations much greater than those shown in steel bars, but the least vibration causes the acquired magnetism to vanish almost completely. If the action of the light is of the same nature as that of a mechanical shock on a magnet and not dependent on the special structure of the magnetic field in Bidwell's experiment, we ought to obtain effects from light in experiments like those of Ewing, if they are sufficiently delicate. I have been able to get very good results from a series of experiments with this object in view. The bars were magnetized in a magnetic field of about 400 C. G. S. units and the current was steadily and rapidly shut off by means of a continuous current rheostat. The slightest vibration caused a sudden fall in the residual magnetism. Extreme care was necessary. Only a small portion of the bar was exposed to the light, as it was found that the magnetizing coil could not be removed without causing the sudden fall in the magnetic strength of the bar. Electric disturbances due to the surface-road and electric light wires had the same effect, and it was necessary to work during the quiet portions of the day. The following is the average result of a number of experiments. Only $3^{cm}$ of the bar was exposed, that is, there was the same surface exposed as in previous experiments, and the light was that of an ordinary gas jet at a distance of six inches; other conditions were the same. The direction of the deflection indicated in every case a decrease of magnetism.

| Rod. | Area exposed to light. | Deflection. |
|---|---|---|
| A | 6·15 $^{sq\ cm}$ | 44·0 |
| B | 4·48 | 26·1 |
| C | 3·06 | 12·5 |
| D | 1·65 | 6·4 |
| E | 3·60 | 13·1 |
| F | 3·60 | 8·4 |
| G | 3·60 | 4·3 |
| H | 3·60 | 0·9 |

These results differ from those of Bidwell in the fact that the deflections here are permanent, even after light has been

* Proc. Roy. Soc., 1890, p. 342.

removed. In my own repetition of Bidwell's experiment, the magnetometer image did not always return to the same spot after the light had been flashed upon the iron and removed. There was in general a partial return, the law or cause of which I was unable to discover. I then attempted a similar experiment obviously suggested by the previous one, namely, that of increasing by light the magnetic strength of a bar which was in a steady field. I here also had great difficulty on account of external vibrations and electrical disturbances. I steadily increased the current up to different strengths and then flashed the light on the exposed portion of the bar and noted increase with the magnetometer. The first series here given is when the field is of about 10–15 C. G. S. units and the second, of about 350 C. G. S. units, $3^{cm}$ was exposed and the light was a gas jet at a distance of 6 inches.

| Rod. | Area exposed. | Deflection—I. | Deflection—II. |
|---|---|---|---|
| A | 6·15 sq cm | none | none |
| B | 4·48 | none | none |
| C | 3·06 | 42 | none |
| D | 1·65 | 6 | 10 |
| E | 3·60 | none | none |
| F | 3·60 | 36 | none |
| G | 3·60 | 23 | 15 |
| H | 3·60 | 7 | 14 |

It is a noteworthy fact that it is only the larger bars from which no deflection was obtained. The conditions were precisely the same for the series and therefore for the larger bars there is either an increased sensitiveness to vibrations coming from without, or the action is dependent on the mass in some manner not understood. It is probably only a small portion of the iron which is so extremely sensitive as to be influenced by light. A slight but sudden increase of the field up to the maximum strength used in this experiment caused a rise in the magnetism of one bar amounting to 125 divisions, while a slight and sudden fall in the strength would also cause a slight increase, when the sensitive state was obtained.

All these results can be effectively accounted for by the assumption of a regular closed magnetic circuit (in iron bars carefully annealed, magnetized, and immediately demagnetized as above described) in which the lines of force return through a thin layer at the surface. The circuit is wholly or partially closed in every case except that of complete saturation, and the thickness of this surface layer depends on the magnetic state of the bar. In Bidwell's experiments, we may suppose the larger portion of the lines of force to return through the surface layer, which is here of considerable thickness. Here

the action of the light is to break or destroy a number of those lines of force. On removal of the acting force, or source of energy, there exists a tendency to return to the original form, owing to action of magnetic lines in the immediate vicinity. In the next two experiments, the instability is of the opposite kind and there is no tendency to return to the original form. In both cases, where the iron was demagnetized by light, and where the iron was magnetized by light, the action is similar to that of a blow under the same circumstances.

While this satisfactorily explains the mechanism of the results of the action of light on a magnetized iron bar, that of the direct action of the light is in doubt. Analogous effects can be obtained from purely mechanical actions and I have obtained them also from the action of electric waves. Whether these quantitatively remarkable results are due to the magnetic or purely mechanical action of light, is unknown. I determined therefore to make some experiment in regard to the action of polarized light on the magnetism of iron. Bidwell has shown that polarized light in the ordinary experiments has the same effect as ordinary light. In order to make a more sensitive action, I obtained from Professor A. W. Wright a number of films of iron deposited on thin glass plates by electrical discharge in exhausted tubes. The method of production and general properties of these films are given in this Journal for January and September, 1877. The films of iron had a brilliant luster and a high degree of transparency and polarized the light transmitted by them powerfully. The films were approximately $2^{cm}$ long and $0{\cdot}5^{cm}$ in width and the thickness was very small, about a quarter of the wave length of red light. The amount of iron in one of these magnets was extremely small; the magnetic moment of the largest one was so small that when suspended by a single silk fiber, the finest obtainable, the magnetic action of the earth's field was scarcely noticeable. But the magnet possesses relatively strong permanent magnetism for the amount of iron involved, in fact, the iron appears permanently saturated. A remarkable feature of this magnetism is its strong resistance to a reversing force. If we assume the reversal of any ordinary magnet by an opposite magnetizing force to be due to the cumulative action resulting when a few unstable molecular magnets are reversed and these produce other unstable groups which are in their turn reversed and so on, then this phenomenon can be explained by the almost total absence of unstable groupings of molecular magnets in the mass of the iron. In a magnetic field of 400 C. G. S. units it required from three to five seconds to reverse it, and in a field of 25 C. G. S. units it was im-

possible to reverse it without tapping. Under these circumstances it was found to be impossible to demagnetize this magnet totally by any of the ordinary methods. The magnetometer used in the previous experiments, while extremely delicate, was not of the slightest use in these, and therefore it was necessary to measure the time of vibration of the magnet itself, with and without light polarized in different directions falling on its surface. The system was almost aperiodic, the magnet coming completely to rest in five half vibrations. No difference in time amounting to 0·2 seconds was observable out of a total of 40 seconds approximately. Owing to the unexpected magnetic behavior of the iron, it was not thought that the light polarized so as to have its vibrations perpendicular to the magnetic axis of the magnet would demagnetize it completely, but that a slight fall from completely saturated state might occur, and so the experiments were continued. The magnet was kept suspended in a field of 600 to 800 C. G. S. units for some time; the field was gradually diminished to 200 C. G. S. units and then torsion for given deflection was measured with and without the application of polarized light. Five complete revolutions of the torsion head caused a deflection of 55° of the magnet without the application of light, while 4·8 revolutions caused the same deflection when light so polarized that the vibrations were perpendicular to the magnetic axis was applied to the surface. There is a possible error of 20° for each of these readings. The same experiment was repeated with light parallel to the magnetic axis of the magnet and a difference in the torsion amounting to 40° was observed. The quantitative difference in the two experiments is very small, but the results of a great number of the observations were taken and were fairly consistent. This apparently shows a difference depending on direction of the plane of polarized light analogous to the demagnetizing effect of an alternating current.

Owing to the anomalous behavior of iron films when placed in a magnetic field and their strong resistance to a reversal of the magnetization, it was thought advantageous to attempt the experiment with a nickel film, since the resistance to demagnetization would probably be much less than for iron films. Although the film which was used contained nearly fifty times the amount of metal of the heaviest of the iron films and was exposed in a field of nearly 2000 C. G. S. units, there existed no appreciable magnetic moment in the nickel and the experiment was given up.

From the results of this investigation the following conclusions may be drawn:

1. An effect of light on magnetism is, in general, easily obtained and depends only on a certain condition of sensibility artificially produced.

2. This condition is, apparently, that a peculiar and unstable distribution of the magnetic lines of force shall exist in the magnet.

3. The action is, in general, a purely mechanical one, similar to the effect of a blow.

4. Evidence of the magnetic action of polarized light has probably been obtained by the use of iron films on glass.

In conclusion, I wish to thank Prof. A. W. Wright for his assistance throughout the investigation. He suggested the subject and general plan of research, and afforded me ample facilities for performing the experiments.

Sloane Physical Laboratory, June 15, 1900.

# SCIENTIFIC INTELLIGENCE.

## I. Chemistry and Physics.

1. *On Radio-active Barium.*—In a preliminary notice Béla v. Lengyel calls attention to the fact that the bodies thus far known which emit Becquerel's rays are of five different kinds, viz., the compounds of uranium, of thorium, polonium, radium, and Debierne's body which is analogous to titanium. Uranium and thorium are well-defined chemical substances, while the three others are merely hypothetical elements. Radium is the best known of these, but from the statements made in regard to it the author believes that it can hardly be regarded as an existing element. In favor of its existence the two principal facts from a chemical point of view are the higher atomic weight found by Madam Curie for the radio-active barium, and the single foreign line found by Demarcey in the spectrum of such material. In regard to the first point, the author thinks that a body which is present in sufficient amount to raise the atomic weight eight units above barium should not fail to reveal itself in the course of various chemical decompositions. He believes, moreover, that the single spectrum-line noticed by Demarcey does not point to the presence of an element closely analogous to barium, for, as is well known, the spectra of barium, strontium, and calcium consist of many sharp lines and less clearly defined bands, similarly grouped in the three cases, and an element almost identical with barium should possess an analogous spectrum. He states also that it should be remembered that these hypothetical elements are always found adhering to other well-known chemical elements. Curie found polonium with bismuth, Giesel found it with lead; radium is attached to barium, Debierne's element goes with titanium. All these radio-active substances come from pitchblende, being separated from it by analytical processes. It is difficult to assume that elements exist which differ from others that are well known in nothing except their radio-activity.

Such considerations as the above led the author to investigate experimentally the question whether radio-active bodies contain new elements or not. He ignited uranium nitrate with two or three per cent of barium nitrate and finally fused the resulting oxides in the electric arc. The mass was dissolved in nitric acid, the solution was evaporated, whereupon a large part of the barium separated as nitrate, then from the decanted liquid a precipitate of barium sulphate was produced which showed radio-activity. The author believes that he has prepared radium synthetically, but does not consider that these preliminary experiments are sufficient to decide with certainty whether this is a definite chemical element or not.

There appears to be a weak point in this supposed synthesis of radium from the possibility that the uranium nitrate used may

have contained the "element" in question, although v. Lengyel does not mention such a possibility. At all events, the result of the experiment makes it seem possible that the radio-activity of uranium may be due to the same cause as that of radium, and perhaps also of polonium and the others.—*Berichte deutsch. chem. Gesellsch.*, xxxiii, 1237. H. L. W.

2. *Mercuric Antimonide, and Stibonium Compounds.*—PARTHEIL and MANNHEIM have prepared mercuric antimonide, $Sb_2Hg_3$, by passing hydrogen antimonide over finely powdered mercuric chloride which was mixed with sand and fragments of glass. The reaction took place slowly, the white mercuric chloride becoming black. This mercuric compound is interesting because like potassium antimonide it gives stibonium compounds when treated with alkyl iodides. The authors have studied its behavior with ethyl and propyl iodides, heated under pressure. They thus obtained the double salts $Sb(C_2H_5)_4I.HgI_2$ and $Sb(C_3H_7)_4I.HgI_2$. By treatment with silver oxide these bodies yielded tetraethyl stibronium hydroxide, $Sb(C_2H_5)_4OH$, and the corresponding propyl compound, from which various salts were prepared.—*Chem. Centralbl.*, 1900, 1, 1091. H. L. W.

3. *The Atomic Weight of Iron.*—This important constant has not been revised since about fifty years ago; meanwhile analytical methods have been much improved, and the sources of error involved in atomic weight determinations have been more carefully studied. In view of these facts, RICHARDS and BAXTER have made a preliminary series of seven determinations by reducing ferric oxide to metallic iron. Their results show that the previously accepted atomic weight, 56, is somewhat too high and that in all probability the value is very near 55·88.—*Zeitschr. anorg. Chem.*, xxiii, 255. H. L. W.

4. *The Physical Properties of Cæsium.*—ECKARDT and GRAEFE have made an elaborate examination of the physical properties of metallic cæsium which was prepared by heating pure cæsium carbonate with metallic magnesium in an iron tube in a current of dry hydrogen. The summary of their results is as follows:

| | |
|---|---|
| Sp. gr. of liquid Cs at 40° | 1·827 |
| Sp. gr. of liquid Cs at 27° | 1·836 |
| Sp. gr. of solid Cs at 26° | 1·886 |
| Solidifying point of Cs | 26·37° |
| Conductivity at 27° (Ag=100) | 3·63 |
| Specific heat | ·04817 |
| Atomic heat | 6·406 |
| Heat of fusion (for 1 g.) | 3·73 cal. |
| Contraction upon solidification | 2·627 vol. per cent. |
| Coefficient of expansion | ·0003948 |

The specific gravity found by the authors corresponds with the value 1·88 previously determined by Setterberg, but it does not agree with the value 2·40003 recently given by Mencke. The latter is probably incorrect, not only in view of the agreement of

the other investigators, but because it gives an atomic volume for cæsium, which is not in harmony with the periodic system.—*Zeitschr. anorg. Chem.*, xxiii, 378. H. L. W.

5. *On Compounds of Telluric Acid with Iodates.*—WEINLAND and PRAUSE have prepared the salt $I_2O_5.2TeO_3.K_2O.6H_2O$, as well as an exactly corresponding rubidium compound, and an ammonium salt which varies from the foregoing in containing $8H_2O$. The potassium salt of a different acid, $I_2O_5.TeO_3.K_2O.3H_2O$ was also obtained. These results are interesting inasmuch as they show that $TeO_3$ forms complex acids with iodates similarly to the oxides $SO_3$, $CrO_3$, $MoO_3$ and $WO_3$.—*Berichte deutsch. chem. Gesellsch.*, xxxiii, 1015. H. L. W.

6. *A Simple Method of Decomposing Chromite.*—For getting this very refractory mineral into a soluble condition FIEBER recommends heating ·5 grams of the finest possible material with six parts of sodium-potassium carbonate for ten minutes in a platinum crucible, then after cooling adding six parts of borax and fusing at a gradually increasing heat, finally over the blast-lamp for three-quarters of an hour. This generally effects the decomposition. If it fails, it is only necessary to add another portion of sodium-potassium carbonate and fuse again.—*Chem. Zeitung*, xxiv, 333. H. L. W.

7. *The Theory of Electrolytic Dissociation and Some of its Applications;* by HARRY C. JONES, 8vo, pp. xii–289, New York, 1900 (The Macmillan Company).—The title of this valuable addition to chemical literature hardly gives a proper idea of the scope of the work. The first chapter, 68 pages, is devoted to an exposition of "The Earlier Physical Chemistry," which serves as an excellent introduction to the main subject of the book. The four chapters are designed to answer the questions: What was physical chemistry before the theory of electrolytic dissociation arose? How did the theory arise? Is it true? What is its scientific use? The author has given very satisfactory answers to these questions, and the book will undoubtedly be useful to those who wish to gain a clear notion of some of the chief points of modern physical chemistry. H. L. W.

8. *Optical Activity and Chemical Composition;* by Dr. H. LANDOLT, translated by JOHN MCCRAE, Ph.D., 12mo, pp. xi–158, London, 1899 (Whittaker & Co., from The Macmillan Company, New York).—This work forms a chapter in Graham-Otto's "Lehrbuch der Chemie." The topics dealt with are the general principles of optical activity, the connection between the rotary power and the chemical composition of carbon compounds, and the connection between the degree of rotation and chemical constitution. H. L. W.

9. *Variation of the Electric Intensity and Conductivity along the Electric Discharge in Rarefied Gases.*—Skinner has shown that very near the anode the electric intensity is very small or zero when the positive column is not striated. He also mentions that with a striated positive column the potential-difference

between the anode and an exploring wire near it, was a minimum when the exploring wire was at a short distance from the anode, so that the apparent electric intensity near the anode was negative. These results are confirmed by HAROLD A. WILSON, who measured the differences of potential between two exploring wires kept at a fixed distance apart in the discharge, which could be brought into any desired portion of the discharge by moving the electrodes between which the discharge took place. This discharge was produced by a storage battery of 600 cells. The gases employed were air, nitrogen, and hydrogen. The positive drop close to the anode was very apparent from the experiments. Very close to the positive electrode there is apparently a very intense ionization. In the negative glow and Faraday dark space there is also ionization in excess. In every kind of electric discharge ionization appears to occur on the metallic electrode when it is red hot and most easily there. The negative ions formed at the surface of the cathode constitute the cathode rays, and produce the ionization which the intensity curves show occurs in the negative glow.—*Phil. Mag.*, June, 1900, pp. 505–516. J. T.

10. *Mechanical possibilities of flight.*—Lord RAYLEIGH in the Wilde lecture published in the Manchester Memoirs 1899, No. 5, discusses this proposition and shows that in order for a man to support himself by a vertical screw by working at the power an average man can maintain for eight hours a day, he would require a screw ninety meters in diameter; and in this estimate no account is taken of the weight of the mechanism or of frictional losses.—*Nature*, May 31, 1900. J. T.

11. *Magnetic Screening.*—The great extension of electric circuits for lighting and for power makes it impossible in most cases to use the ordinary form of mirror galvanometer. H. DU BOIS and A. P. WILLS discuss the subject of the protection of galvanometers from outside changes in the magnetic field produced by the commercial employments of strong currents. The cases of iron cylindrical shells and of spherical shells is treated and the results are used by H. Du Bois and H. Rubens in the construction of a protected or armored galvanometer (Panzergalvanometer). Cast-steel cylinders having a radius ratio of air space 1·5 to 1·6 and spherical cast-steel shells 1·3 to 1·4 give in general this order of protection: one shell, 10; two shells, 100; three shells, 1000.—*Ann. der Physik*, pp. 78–95. J. T.

12. *The Sun's Corona.*—Mathias Cantor in the Ann. der Physik for March, 1900, believes from his experiments that a rarefied gas through which an electrified discharge is passing shows no perceptible absorption corresponding to its emission spectrum, and Professor Fitzgerald in Nature, May 3, 1900, remarks that this fact confirms the suggestion that the sun's corona is an electrical discharge around the sun since the bright spectrum line of the corona is not represented by a dark line in the solar spectrum. E. PRINGSHEIM criticises severely the results of Cantor and believes that he has not taken suitable precautions in his experiments.

He points out that the discharge through the gases was an intermittent one and the gases were only a portion of the time in that condition when, according to Kirchhoff's laws, an absorption was to be expected. For the remaining portion of the time the light of the arc lamp employed could go through the gas completely unabsorbed. Furthermore since the spectral lines in a Geissler tube represent homogeneous light, an absorption could only be expected, according to Kirchhoff's laws, in a very narrow spectral region. In order to show it, a spectrum of a large dispersion must be employed and a narrow slit, in order that no light of the neighboring portion of the arc spectrum can intrude upon the homogeneous portion under examination. These precautions were not taken by Cantor.—*Ann. der Physik.*, No. 5, 1800, p. 199–200.

J. T.

13. *On some Properties of Light-struck Photographic Plates;* by FRANCIS E. NIPHER. (Abstract by the author.)—A paper with the above title recently published* by the Academy of Science of St. Louis, deals among other things with some features which seem to be new in photography.

In a general way it is probably true that any plate, upon which a camera impression has been made, may be developed either as a positive, or as a negative. Suppose the object to be a white design on a black ground. Let the camera be replaced by a printing frame, containing the plate and an opaque stencil with some design punched through it. Place this plate at any distance from a known source of light. Give any exposure to the plate. If the plate be now developed at a considerable distance from the lamp, a negative image will appear. The lamp should be vertically over the developing bath. If the bath in a similar exposure is taken nearer to the lamp, the negative will be a poorer one. At a still nearer distance, nothing will develop. In the parlance of the photographer, the plate will fog. This is called a zero plate. If the plate be developed at a point still nearer the lamp, the picture will appear as a positive. The conditions of zero plate as a function of exposure is now being studied. A given exposure is a time integral of the effect due to any given illumination, at the point of exposure.

The paper referred to gives half-tone reproductions of photographs thus developed in the light as positives. In one an attempt was made to "fog" a plate into a zero condition before it was put into the camera for exposure to a street scene. The plate was fogged by X-rays for two hours, and was exposed in the camera for ten minutes. It was developed in a hydrochinone bath, within one foot of a sixteen-candle lamp. The result is a superb positive of the street scene in which the moving objects leave no trace. The plate was an instantaneous isochromatic plate by Cramer.

Another picture reproduced was a picture on the same kind of plate, obtained by an exposure of one minute in the camera. The

* No. 6, vol. x, Transactions.

street was strongly lighted, and the plate was converted into a zero condition, and the positive was then produced, during the single minute and while in the camera.

It is also found that the camera exposure may be shortened, by fogging the plate in open lamp-light before it is put into the camera. If the plate is to be developed within 20 cm. from a sixteen-candle lamp, these fast plates will be put into a zero condition by holding them for 90 seconds at a distance of one meter from the lamp. When exposed in the camera such a plate yields a perfect positive picture. If traces of fogging appear, the plate should be moved nearer the lamp. The precise conditions which yield the best results have not yet been determined, nor is it yet known how short the exposure may be made. Some of the plates turn out badly until experience has been gained.

It is evident that if a similar change can be produced in the operation of printing, so that a positive print may be obtained from a positive plate, the dark-room may perhaps be dispensed with for purposes of developing.

In some cases the most sensitive plates have been exposed for from three to four hours to brilliantly lighted street scenes, with the diaphragm fully open. There is not the least trouble in developing such plates, as positives, in a strongly lighted room. In general, the greater the exposure, the darker the developing room must be in order to get a zero or a negative result.

Large pin-hole images of the sun may be developed in this way, and there appear to be many ways in which the process may yield good results. One of the incidental features of value is that a little of what photographers most fear does not interfere with the results.

## II. Geology and Mineralogy.

1. *A Monograph of Christmas Island (Indian Ocean): Physical Features and Geology;* by Charles W. Andrews. With descriptions of the Fauna and Flora by numerous contributors. Pages x, 337; plates xxii. London, 1900 (British Museum of Natural History).—The unique character of Christmas Island, in its position, history, and life, gives peculiar interest to this account of the results obtained from the ten months' vigorous explorations made by Mr. Andrews, of the Geological Department of the British Museum.

Christmas Island has an area of 43 square miles, and rises in places to a height of 1000 feet; it is covered with a dense tropical vegetation. It is situated in the eastern part of the Indian Ocean, 190 miles to the south of Java, 900 miles northwest of the coast of Australia, and 550 miles east of the atolls of Cocos and North Keeling. The submarine slopes about it are so steep that a depth of 1000 fathoms is found within two or three miles of the coast, while to the north, a depth of 3200 fathoms was found (Maclear Deep), and to the south and southwest, of 3000 fathoms

(Wharton Deep). The island is described as forming the summit of a submarine peak, the base of which rises from a low saddle which separates the two abysses named, and on the western end of which the Cocos-Keeling Islands are situated. Its peculiarly isolated position, hence, is most striking. Its history is also unique, since, although known to navigators since the middle of the 17th century, no one seems to have penetrated into the interior until 1887, and, as remarked by Dr. Murray, down to a few years ago it was probably the only existing tropical island of any large extent that had never been inhabited by man, savage or civilized. Its animal and vegetable life, therefore, are thus far almost unchanged by the conditions introduced by human life.

Geologically, the island consists largely of elevated Tertiary limestones with extensive series of eruptives; briefly, it may be considered as an ancient atoll raised to a considerable height above the level of the sea. The "central nucleus" is made up of compact yellow limestone in places very hard and showing no traces of bedding or jointing. This is referred to the Eocene (or Oligocene) and is accompanied by basalts and trachytes both beneath and between the beds. The total thickness of these older Tertiary and accompanying volcanic rocks is estimated to be 600 feet. Forming the mass of the island is the Miocene Orbitoidal limestone, separated from the older rocks by basalts and basic tuffs. The higher elevations are dolomitic limestones containing 34 to 41 p. c. of magnesium carbonate; these show traces of coral structure and imperfect remains of Foraminifera. Thick beds of phosphate of lime, in part limestone beds altered by overlying guano, in part phosphatized volcanic tuffs, occur on some of the elevated points and have proved to be of economic value. The Tertiary limestone, especially the Miocene, forms abrupt vertical cliffs, sometimes 250 feet in height, along a large part of the coast line. A series of terraces is also noted around the shore, and outlying the whole is the fringing coral reef. The author remarks upon the remarkable development of elevated Tertiary rocks and the difficulty in explaining their deposit over an area so isolated. He adds that the great thickness of reef limestone, required by the Darwinian theory of atoll formation, is not found, and although there may be some evidence that subsidence did occur in the history of the island, it is clear that it was not for any long period nor of any great extent. It is interesting to recall in this connection the similar observations recently made by Agassiz on the elevated Tertiary limestones of the Fijis and other islands of the Pacific.

The life of the island is fully described from the collections made and it is shown to be to a remarkable extent endemic. Thus of the 319 species of animals recorded, about 45 per cent are described as peculiar to it, although this percentage may perhaps be reduced when the fauna of Java and other neighboring islands is more minutely known. For example, of the mammals, all are peculiar species except one; of six reptiles, four are pecu-

liar; of fourteen species of land shells, six are peculiar, etc. The author gives an interesting summary of the conditions, as to winds and ocean currents, which have been instrumental in the introduction of the fauna and flora.

2. *On the Lower Silurian (Trenton) Fauna of Baffin Land;* by CHARLES SCHUCHERT. Proc. U. S. Nat. Mus., vol. xxii, pp. 143–177 (with plates xii–xiv), 1900.—The author reports upon several collections placed in his hands for study. The following excellent summary is quoted from page 175 of the report:

"The only Lower Silurian horizons known in northeastern Arctic America are of Trenton and Utica age. The latter zone appears only on the north shore of Frobisher Bay, but the Trenton is found in various places from the north shore of Hudson Strait to latitude 81° north. The Lower Silurian is thickest on Akpatok Island, where it is from 400 to 500 feet in depth. Dr. Bell, however, estimates the entire thickness of these strata in this region to be not less than 900 feet.

"In Baffin Land, and apparently elsewhere in Arctic America, the Lower Silurian strata rests unconformably on old crystalline rocks. To the north of Baffin Land, the former are overlain by beds of Niagara or Wenlock age.

"The Trenton faunas, occurring in various places around the insular Archæan nucleus of North America, have much in common, and this indicates that the conditions at that time were very similar, while the sea was in communication throughout. As yet, however, the distribution of the strata, together with their faunas, are well known only to the south and southeast of the Archæan nucleus, yet that of the west (Manitoba) and of the northeast (Baffin Land) show direct communication.

"The Baffin Land fauna had an early introduction of Upper Silurian genera in the corals *Halysites*, *Lyellia*, and *Plasmopora*. In Manitoba similar conditions occur in the presence of *Halysites*, *Favosites*, and *Diphyphyllum*. Other Upper Silurian types do not appear to be present.

"The Trenton fauna of Silliman's Fossil Mount, at the head of Frobisher Bay, has seventy-two species, of which twenty-eight are restricted to it. This fauna shows an intimate relationship with that of the Galena of Minnesota, Iowa and Wisconsin. Fifty-seven per cent of the species of Baffin Land also occur in the Galena of the regions just mentioned.

"The Trenton fauna of Baffin Land shows that the corals, brachiopods, gastropods, and trilobites have wide distribution, and are therefore less sensitive to differing habitats apt to occur in widely separated regions. On the other hand, the cephalopods, and particularly the pelecypods, indicate a shorter geographical range. The almost complete absence of Bryozoa in the Baffin Land Trenton contrasts strongly with the great development of these animals in Minnesota and elsewhere in the United States."

3. *A Preliminary Report on the Geology of Louisiana;* by GILBERT D. HARRIS and A. C. VEATCH, Part V, Geology and

Agriculture, plates 1–62, figures 1–7, map, pp. 4–354, 1899. (Geological Survey of Louisiana, Wm. C. Stubbs, Director.) The author recognizes in Section II the following formations:

*Cretaceous* series—Ripley stage.

*Eocene* series—Midway, Lignitic, Lower Clarborne, and Jackson stages.

*Oligocene*—Vicksburg and Grand Gulf.

*Lafayette*—

*Quaternary*—(including the Columbia of McGee and Biloxi sands of Johnson) Basal gravel, Port Hudson, Loess and Yellow Loam, Alluvium and recent coastal formations.

In Section III—special reports—nine miscellaneous reports are given by various authors, the last on "Wood-destroying Fungi," by Professor Atkinson.

4. *Geology of Panama.*—In a study of the geology of the isthmus of Panama recently published by Messrs. BERTRAND and ZURCHER,* Bertrand draws the following important conclusions regarding the probability of earthquake shocks in the Panama region:

"There are no volcanoes near Panama, all eruptions having ceased since the Miocene; this is the first and most important point of all.

Since the earthquake of 1621, which is in reality disputed, there have been in the region only very feeble shocks, a part of which were due to the echo of far distant earthquakes.

The depression made use of by the Panama canal project is not a transverse fracture.

The sinking of the Pacific coast, and especially the subsidence of the bay of Panama, of which there are numerous indications, are not phenomena now going on but finished, so far at least as regards the present geological epoch. There is there no special reason for crustal movement.

Finally, the plan of the lines of folding and the distribution of volcanic and seismic activity following these lines, shows that Panama is situated in a sort of dead angle, in a tranquil zone, at an equal distance north and south from the lines of disturbance.

Thus all considerations, whether statistic, volcanic or seismic, lead to the same conclusion, that Panama is the most stable and least menaced region of Central America." L. V. P.

5. *Enrichment of Mineral of Veins by later Metallic Sulphides;* by WALTER HARVEY WEED. Bulletin of the Geological Society of America, vol. II, pp. 179–206.—Secondary sulphide enrichment is certainly one of the most interesting subjects of economic geology, and, as noted by Mr. Weed in the opening pages of his article, is one upon which surprisingly little has been written, considering its scientific and practical importance. Among prominent writers on ore deposits, De Launay, Posepny, Emmons and

* *Études geologiques sur l'isthme Panama* and *Phénomènes volcaniques et les tremblements de terre de l'Amerique Centrale*. Paris, 1900.

Kemp have mentioned the subject, but the present paper is the first to treat it separately and comprehensively.

After some introductory remarks and definitions a discussion follows of the chemical reactions which take place during the leaching of the mineral contents of the gossan zone; then the chemical processes concerned with mineral deposition in the enrichment zone and of the alterations of various vein minerals, are considered. A more extended description and discussion of the manner of occurrence of secondary enrichments is then entered upon, dealing with the deposits of copper, silver and zinc in prominent localities, here and abroad, which have been carefully studied.

To the material taken from various outside sources Mr. Weed has added much valuable information, gained as a result of his own extensive observations and studies of the ore deposits of the West.

The conclusions reached are worthy of careful notice and are quoted here in full. Conclusions: "From what has been shown it is concluded that later enrichment of mineral veins is as important as the formation of the veins themselves, particularly from the economic standpoint. The enrichment is usually due to downward-moving surface waters, leaching the upper part of the vein and precipitating copper, silver, et cetera, by reaction with the unaltered ore below. In many cases the enrichment proceeds along barren fractures and makes bonanzas. In others it forms films, pay streaks, or ore shoots in the body of leaner original ore. In still other cases the leaching, transportation, and redeposition are performed by deep-seated uprising waters acting upon the vein.

As a consequence of this, veins do not increase in richness in depths below the zone of enrichment.

The practical bearing of the phenomena described and the deduction drawn from them will, I think, be apparent to every mining engineer and geologist. If my views be correct, the future of many ore deposits is to be judged in the light of these facts, and the value of the mine must not be based on the presumption that the ore will continue in unabated richness in depth."

A forthcoming paper, which is promised on the secondary sulphide enrichments of Butte, Mont., will be awaited with no little interest. C. H. W.

6. *Mineralogical Notes.*—Number 7 (vol. i) of the Geological Series of Publications by the Field Columbian Museum (pp. 221–240), by Dr. O. C. Farrington, contains an acconnt of several new mineral occurrences and also a description of the fine calcite crystals from Joplin, Missouri. The rare species *inesite* is noted from a mine near Villa Corona, Durango, Mexico. It occurs in tufts of radiating crystals of flesh-red color. These correspond in angle with the results of Scheibe and show the new forms $k$ ($\bar{1}\bar{1}\cdot0\cdot12$) and $s$ ($9\bar{4}6$). The following analysis was made:

| | $SiO_2$ | MnO | FeO | CaO | MgO | $H_2O$ (cryst.) | $H_2O$ (const.) |
|---|---|---|---|---|---|---|---|
| G.=2·965 | 44·89 | 26·53 | 2·48 | 8·24 | *tr.* | 5·99 | 2·21=100·34 |

From this, the composition $H_2(Mn, Ca)_6Si_6O_{19}+3H_2O$ is deduced, which varies somewhat widely from the results hitherto obtained.

*Culedonite* in distinct crystals is noted from the Stevenson-Bennett mine, Organ Mountains, New Mexico; also *gay-lussite* from Sweet Water Valley, Wyoming. The use of *dolomite* as money by the Indians in Lake County, California, is noted. The tokens are shaped in cylindrical forms and burned, which brings out reddish streaks in the oxidation of the iron, and then polished and perforated. In this form they are highly valued by the natives.

The various types of the beautiful Joplin crystals of calcite from Joplin are described and well figured. The observations form an important addition to the literature of the species.

7. *Tabellen zur Bestimmung der Mineralien mittels äusserer Kennzeichen.* Herausgegeben von Dr. ALBIN WEISBACH. Fünfte Auflage. Pp. 106. Leipzig, 1900 (Arthur Felix).—The Determinative Tables of Prof. Weisbach, first issued in 1866, are so well known by those interested in mineralogy that their value hardly needs to be remarked upon here. Based upon external characters alone, they give the student a simple means of determining species, applicable in ordinary cases, and teach him to use his powers of observation with accuracy and discrimination.

8. *Repertorium der Mineralogischen und Krystallographischen Literatur vom Anfang d. J. 1891 bis Anfang d. J. 1897, und Generalregister der Zeitschrift für Krystallographie und Mineralogie*, Band xxi–xxx. Herausgegeben und bearbeitet von E. WEINSCHENK und F. GRÜNLING. II. Theil (Generalregister von F. Grünling). Pp. 394. Leipzig, 1900 (Wilhelm Engelmann).—The First Part of this Index has already been noticed in the present volume of this Journal (p. 229). Part II, now issued, completes the work, which is invaluable for every one interested in the progress of Mineralogy. The fact that this general index extends to nearly four hundred pages shows strikingly the immense amount of material in the Zeitschrift to which references are made.

## III. BOTANY AND ZOOLOGY.

1. *Les Carex de l'Asie orientale;* by A. FRANCHET, Nouv. archiv. du muséum d'hist. nat., Ser. 3, vols. 8–10, Paris, 1896–1898.—The present comprehensive work deals with the vegetation of *Carex* in eastern Asia, of which 274 species are described and a number of new ones are figured; the geographical distribution is given to each species. Inasmuch as the number of species of *Carex* is in the neighborhood of some 800, the author has rendered excellent service to the study of the genus by presenting figures of the new with their general habit and other details. Eastern Asia, and especially Japan, appears to be ex-

ceedingly rich in representatives of this genus, in spite of the fact that many large areas of, for instance, China and even Japan are yet unexplored, and the extreme north-east is almost unknown, save the collections brought home by Eschscholtz and Kjellman. In looking over the vast material treated in the present work, one notices readily that a number of very peculiar types are characteristic of that part of the world; there are, indeed, several which are utterly unlike the ordinary types of *Carex: C. podogyna*, for instance, possesses a utricle borne on a pilose stipe, 4–8$^{mm}$ in length; in *C. Nambuensis* there are several lateral androgynous spikes on long, filiform peduncles; *C. pachygyna* has inflated, bladeless sheaths subtending globose, pistillate inflorescences; the leaves of *C. capilliformis* are numerous, long and capillary; in *C. hakkodensis* and *C. rhizopoda* we meet with types of very much the same habit and structure as the singular *C. lejocarpa* and *C. circinata; C. gentilis* shows the habit of the *Indicæ* Tuckm., while *C. moupinensis* reminds one of a *Scirpus* or *Rhyncospora* rather than a *Carex*. Only two dicœcious species are known from eastern Asia: *C. Redowskiana* C. A. Mey. (*C. gynocrates* Wormskj.) and *C. grallatoria*. Among the monœcious we meet with the circumpolar *C. rupestris*, and with *C. pyrenaica*, of which the latter shows a most singular geographical distribution: Mountains of Middle- and South-Europe, western Asia, New Zealand, Rocky Mountains of Colorado and Alaska. *C. pauciflora* and *C. microglochin* are, also, represented in this Flora; *C. incurva* is reported from West China, and is known besides from so remote localities as the Arctic region, the Magellan strait, Himalaya, the coast and higher mountains of Europe. The cosmopolitan *C. vulgaris* is of course, included, besides some species which are very abundant in Europe, as for instance: *C. vesicaria*, *C. filiformis*, *C. Pseudocyperus*, *C. Buxbaumii*, etc.

It appears, altogether, as if the genus in eastern Asia possesses a number of species in common with other parts of the globe, and many that are not known from elsewhere. But in these special types, special to eastern Asia, are several which actually represent forms analogous to those which inhabit other parts of the world. There is a series of *Microrhynchæ*, of *Melananthæ* and even of *Dactylostachyæ*, which correspond very well with such types as exist in Europe, Asia and America. It is this part of the work, the geographical distribution in connection with the characterization of the various types, so excellently done by Franchet, which makes his treatise of the East Asiatic *Carices* the most important and instructive in this line of studies. T. H.

2. *Systematische Anatomie der Dicotyledonen;* by H. Solereder. Stuttgart, 1899—"Ergo species tot sunt, quot diversæ formæ seu *structuræ* plantarum, rejectis istis, quas locus vel casus parum differentes (Varietates) exhibuit, hodienum occurrunt"—these words of Linnæus may be well understood as an indication of the importance of structural characters to systematic work in

Botany, but fully a century elapsed before this thought ripened and became realized as "the anatomical method" nowadays almost universally adopted in the scientific world. French botanists, prominent among whom were Mirbel and Chatin, were the first to take up the idea, that affinities and divergences in the vegetable kingdom might be sought in the internal structure, and the rapid increase in the number of genera and species made it almost necessary to invent other characters than those supplied by the study of morphology alone. In large genera it had, already, become difficult to distinguish the species of closely allied types satisfactorily, and although the very beginning of the anatomical method was purely for the sake of applying the internal characters in the service of systematic work, the study of plant-anatomy soon broadened into other lines, where the anatomy became a branch of its own, making the first and principal foundation for development of physiological research. It is the most rational development of science, when we look back at the work of the earlier botanists, when they began to discriminate organs of plants and compose the systems, and then gradually became aware of natural groups of plants, until genera and species became adopted as a means of expressing in brief the mutual affinities. Then followed the doctrine of morphology, first as a mere guide in systematic research, the terminology; then it gradually developed into the study of analogies and homologies amongst the plant-organs themselves, while contemporarily anatomical research was found to be useful for controlling the validity of morphological identities. Soon anatomy was applied as an aid in systematic work, and it is this branch of Botany which Dr. Solereder has illustrated in his present book.

In looking through the pages of this elaborate work, one gets an idea of the history of the anatomical method from its beginning to its present stage, and it is, really, an enormous quantity of labor that has already been bestowed upon this line of Botany. It seems as if the first, or at least the most effective, impulse was given in the works of Radlkofer and Vesque, and since then a number of other botanists have taken the subject up with strenuous efforts to prove the validity of anatomical characters. And so far have we reached now in the last decennia that no systematic work seems complete unless this method is considered. Engler's and Prantl's systematic treatise of the natural orders is an excellent example of what great importance is attributed to anatomical characters, and the results of such studies are, really, twofold: they bring to light a number of structural details, more or less applicable to demonstrate the affinities between many genera and species, and, moreover, we obtain by these same results an accumulation of data useful to the understanding of the internal life of the plants, the structure of the tissues, etc. From these may again be drawn conclusions as to the functions of the structural elements, their necessity to plant-life. The study of anatomy became thus

greatly encouraged when botanists discovered that such observations might, also, be useful to classification, and it is no exaggeration to say, that the anatomical method has brought out a keener interest in the study of anatomy, than if plant-structures were worked up for the mere sake of learning how plants are built.

Never before have botanists cared to give so many detailed accounts of the internal structure of the reproductive and vegetative plant-organs as they do now, and moreover, this same method has given rise to another still more modern branch of Botany, generally known as "ecology," which has attracted so much attention lately. From the knowledge of the structure, considered by itself, investigations have been broadened into the study of its application to systematic botany, while at the same time these same anatomical characters have thrown light upon the connection between these and the conditions under which plants live. But investigations of that kind require long time and steady attention, and it is very complimentary to European botanists that so much work has already been accomplished in this line: "the anatomical method." The large number of papers published upon the subject are, however, very scattered, and there has been great need for a book in which all the facts hitherto known, were brought together in systematic form. It must be said that the author has been very successful in his compilation of this enormous material to which he has himself contributed extensively. Besides giving a skillful and thoroughly scientific representation of the anatomical characters of dicotyledonous plants, the author has rendered excellent service to further studies by appending a bibliography to each of the orders treated. It would be impossible to review all the results which are laid down in this book, inasmuch as it is not a book to be simply read, but to be studied. A very detailed account is given of each order, including a large number of genera and species, and much can be learned about the anatomy of the root, the stem and the leaves, as these have been treated in their various modifications. The anatomical characters are represented as generic or specific, and it is very interesting to see the great variation that exists in a number of species, even of the same genus, when we consider, for instance, the mere structure of epidermis with its stomata and hairs, which furnish so many and such prominent distinctions. Very important characters are, also, derived from the modifications that are frequently met with in the mesophyll of the leaf or the bark of the stem with its reservoirs, as cells or ducts, the contents: crystals or liquids; moreover, the very varied development of the mestome in root, stem and leaf, the structure of the pith, etc.

But when we look at the material, upon which these investigations are based, it is at once noticed, that only a relatively small number of North American plants have, so far, been studied from this viewpoint. This ought to give an impulse to similar studies in this country, inasmuch as the North American vegeta-

tion contains so many types which no doubt are of great interest anatomically, and might even serve to solve various difficult problems in systematic botany. It is sad to see, however, that anatomical work is so little appreciated in this country, while physiological research seems to be "fashionable." And it is very astonishing that American investigators seem constantly to overlook the importance of morphological and anatomical research as the principal foundation of physiological work.

Systematic Botany in this country had prominent leaders in Nuttall, Elliott, Torrey and Gray, but we see no reason why this branch of Botany should not be extended still further, in the same scope as abroad. Europe has the advantage, however, of having had a systematic epoch, a morphological and an anatomical, followed by a physiological, while in this country physiological research was taken up before the systematic had been more than justly commenced. While recommending Dr. Solereder's book to students in this country, we hope that American investigators will take so much interest in the work that the second edition may, also, contain results gained by anatomical studies of North American genera. T. H.

3. *Éléments de Paléobotanique*, par R. Zeiller, Ingénieur en Chef des Mines, Professeur à l'École Nationale Supérieure des Mines. Pp. 421, 8vo. Paris, 1900. (Georges Carré et C. Naud Éditeurs, 3, Rue Racine.)—The present handsome volume has been prepared from the botanical standpoint, and forms an important addition to the small but growing group of text-books on the subject which Lesquereux twenty-five years since considered yet in its "infancy." The work of an accomplished systematist, the various groups of fossil plants and their principal forms and relationships are treated with charming clearness and precision. This text is not only a most timely one to the special student, but will be indispensable to the general reader since it displays so clearly the progress which has been made in Paleobotany, and the light which fossil plants shed upon problems of development and descent. The more important structural details are succinctly treated, and a chapter on Floral succession is added. The 210 figures inserted in the text add much to convenience of use, and the volume is a highly satisfactory one in every respect.

G. R. W.

4. *Lehrbuch der Pflanzenpalaeontologie mit besonderer Rücksicht auf die Bedürfnisse der Geologen ;* von Dr. H. Potonié. Pp. 402, 8vo; with 3 plates and 355 text figures. Berlin, 1899. (Ferd. Dümmlers.)—Differing essentially from Zeiller's text-book, that of Potonié approaches the subject of fossil plants with reference first to the needs of the stratigrapher; thus these two works are in a large measure supplementary to each other. The treatment is in fact more distinctly geological than in the case of any of the text-books on Paleobotany which have yet appeared.

The opening chapter on Vermeintliche und Zweifelhafte Fossilien is very interesting, and the closing one—Charakterisirung

der Fossilen Floren—is a useful résumé. The profuse introduction of illustrations throughout the body of the work is a most commendable and labor-saving feature in which it excels. The ferns are given extended treatment in consonance with their stratigraphical importance, while the generalized group of ancient plants now known as the *Cycadofilices* receive a careful structural description. Though giving, in accordance with the general plan of the work as outlined, the greater prominence to earlier forms, the author has yet found space to include many of the more fundamental details of structure characterizing the representative groups of fossil plants. The colored frontispiece showing a Carboniferous landscape is new and effective. Both this and the preceding text-book must prove widely useful. G. R. W.

5. *The Birds of Eastern North America. Part II. Land Birds.* Key to the Families and Species; by CHARLES B. CORY, Curator of Department of Ornithology in the Field Columbian Museum. Pp. i–ix, 131–387. Chicago, 1899 (Special edition printed for the Field Columbian Museum).—The second part (this Journal, viii, 398) of Mr. Cory's classified catalogue of North American Birds has recently been issued. It is liberally illustrated and will be found very useful by the many who are interested in this subject.

6. *Zoological Results based on material from New Britain, New Guinea, Loyalty Island and elsewhere, collected during the years 1895–1897;* by ARTHUR WILLEY. Part iv, pp. 357–530, plates xxxiv–liii; May, 1900. Cambridge (University Press).—The earlier parts of this important series of papers have already been mentioned in this Journal (vii, 79, 322; viii, 398). The present part contains ten papers (Nos. 18 to 27) by different authors. Among these may be mentioned as of especial interest the description by J. J. Lister of *Astrosclera willeyana*, the type of a new family of Sponges.

7. *Das Tierreich. Eine Zusammenstellung und Kennzeichnung der rezenten Tierformen.* Herausgegeben von der Deutschen Zoologischen Gesellschaft. Generalredakteur, FRANZ EILHARD SCHULZE. 9 Lieferung. *Aves*, Redakteur, A. REICHENOW. *Trochilidæ* bearbeitet von ERNST HARTERT. Pp. i–ix, 1–254, with 34 text figures and alphabetical Index. Berlin, 1900. (R. Friedländer u. Sohn.) Earlier numbers of this great work have been noticed in these pages. The present part includes the family *Trochilidæ* of the Birds and has been prepared by Mr. Ernst Hartert of the Zoological Museum at Tring, England.

## IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Solar Eclipse.*—The total solar eclipse of May 28th was observed under exceptionally favorable weather conditions both in this country and Europe. Nowhere on the line of totality did clouds interfere with the observations. In consequence a great quantity of material was obtained, but as yet no results have been announced.

In addition to photographic and spectroscopic work, the bolometer was used by at least two parties with special reference to variations of heat radiation in the rifts and streamers of the corona near the sun's limb. The corona showed a conformity to the types of the last three periods of minimum sun spots so close as to be very striking even to the naked eye. The equatorial streamers were of moderate extent, and the curved polar rays sharply defined to very near the photosphere. W. B.

2. *Lessons in Elementary Physiology*; by THOMAS H. HUXLEY, LL.D., F.R.S., edited for the use of American Schools and Colleges by FREDERIC S. LEE, Ph.D. Pp. 577, 8vo. New York, 1900 (The Macmillan Company).—Huxley's Physiology is so well and favorably known to teachers and students of biology that an extended review of the aim and methods of the book is scarcely necessary in this place. Despite the marked advances in physiology since the preceding revision of the Lessons in 1885, many teachers have felt reluctant to abandon the book, owing to the many points of excellence which it retained. Indeed, it can fairly be stated that few text-books of science equal Huxley's Lessons in the clearness of exposition and a type of analytic treatment which has contributed largely to the development of a proper scientific attitude. The American publishers are therefore to be complimented in having secured the assistance of Professor Lee in a new revision which is extremely satisfactory. The histological portions have appropriately been transferred from their former separate chapter to the descriptions of the various tissues to which they apply. The descriptions of the chemistry of the blood and lymph have been revised and extended; the chapter on digestion has been corrected and greatly improved; statistics of nutrition have been added and the metric system has been introduced. The parts dealing with the nervous system and innervation have been rewritten almost entirely and have been adapted to the recent progress in this department of physiology. Many new illustrations and diagrams have been inserted; and though the book has grown by nearly 200 pages, the spirit of the earlier work is retained. We cannot refrain from quoting from Dr. Lee's Preface the concluding sentence, which describes the attitude of more than one physiologist towards Huxley's Lessons: "The present writer has performed his task with a long-standing feeling of affection for the pages which introduced him to the study of Physiology, and first gave him a clear insight into the nature of scientific conceptions and scientific reasoning."

L. B. M.

3. *Ostwald's Klassiker der Exakten Wissenschaften.* Leipzig, 1899 (Wilhelm Engelmann).—Number 109 of this valuable series has recently been issued, it contains a memoir entitled "Ueber die Mathematische Theorie der elektrodynamischen Induction von Riccardo Felici." Translated by Dr. B. DESSAU (Bologna) and edited by E. WIEDEMANN (Erlangen).

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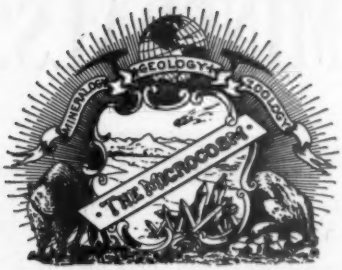


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(1) Described in this Journal Sept., 1895. (2) Ibid Nov., 1887. (3) Proc. Roch. Acad. Sci. Vol. I. (4) This Journal Aug., 1888. (5) Ibid July, 1893. (6) Ibid June, 1894. (7) Ibid Nov., 1892.

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